KINETICS OF THE SOLID-LIQUID PHASE-TRANSFER CATALYZED DEPROTONATION & N-ALKYLATION OF ACETANILIDE

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SUMMARY

The kinetics of the N-benzylation of acetanilide via liquid-liquid phase-transfer catalysis (PTC) have been studied. Benzyl chloride was used as the benzylating agent. In these studies tetra-n-butylammonium chloride, tetra-n-octylammonium bromide, tetra-n-heptylammonium bromide, aliquat 336, tetraethylammonium bromide, benzyltrimethylammonium bromide were used as the phase-transfer agents. KOH and KOH / KCl base and salt combinations were used to create a basic media.

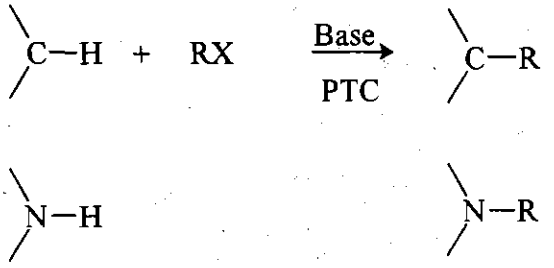
The kinetics of the N-benzylation of acetanilide via solid-liquid phase-transfer catalysis (PTC) in the presence and absence of catalyst have been previously studied. Mechanisms and phase designations have been proposed for the liquid-liquid N-benzylation of acetanilide in the presence and absence of a catalyst. Kinetic data has been collected by varying [H_2O], [OH^-], [Cl^-], [acetanilide], [catalyst] and [benzyl chloride]. Data supports the proposed mechanisms and suggests the benzylation is reaction rate limited rather than mass transfer rate limited.

CHAPTER I

HISTORICAL INTRODUCTION

In organic synthesis an abundance of reactions include highly reactive inorganic reagents. Phase transfer catalysis (PTC) is a technique for facilitating the reaction between reagents located in different phases by taking one reagent from its normal phase into the phase of the second reactant where reaction can take place.

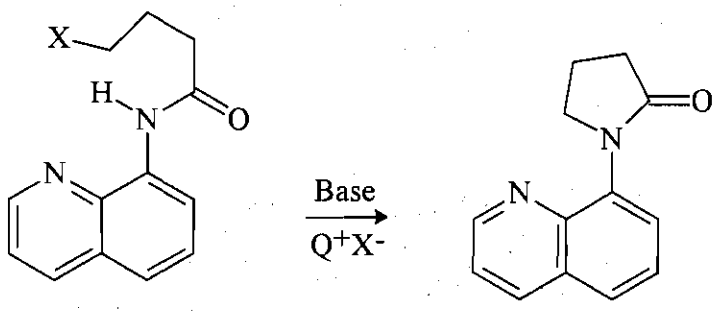
Among the most important organic reactions in which PTC is employed are base promoted C- and N- alkylations.



With PTC convenient, inexpensive, and relatively safe bases such as NaOH and K_2CO_3 may be used and bases such as alkoxides, amides or hydrides can be avoided. It is a fact that about 60 % of commercial PTC applications involve the hydroxide ion.[1]

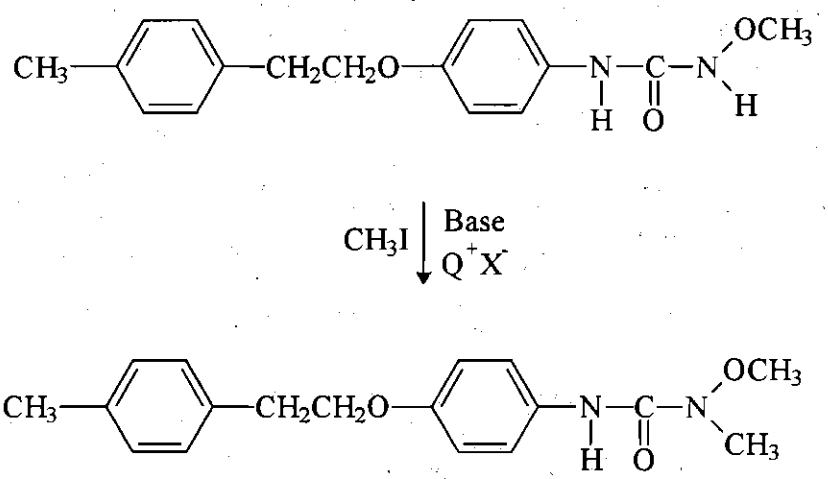
The deprotonation and subsequent alkylation of amides by hydroxides is an example of an important reaction that has been successfully carried out using PTC. A wide variety of N-alkylated amides have been found useful because of their biological

activity. For instance, 1-(8-quinolyl)-2-pyrrolidone (1), (pain killer) and its derivatives have been successfully prepared using PTC.[2]



(1)

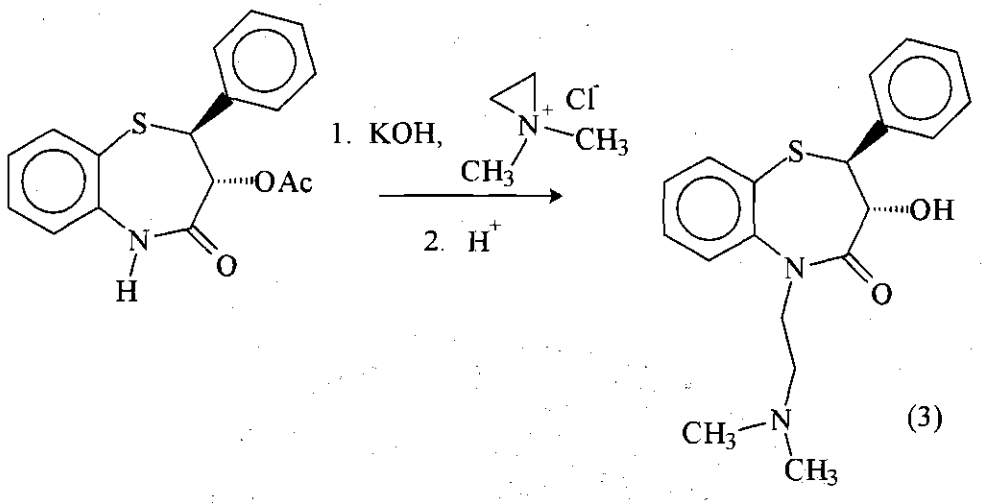
The herbicide (2) has been prepared in 95 % yield thanks to PTC techniques.[1]



(2)

Also, Diltiazem© (3) , a benzothiazipine derivative, has been alkylated using PTC. Diltiazem more commonly called Cardizem ® CD is the leading drug used in the treatment of hypertension.[3]

N-alkyl derivatization of sulfonamides by PTC was used in the GC analysis of diuretics in human urine.[4] The use of PTC in the N-alkylation of sym-N,N'-



Cardizem ® CD

Diarylureas for use as stabilizers for explosives is another important use of this technique.[5]

The significance of PTC in synthetic routes that take advantage of N-alkylations is clear; however, the kinetic and mechanistic details of these reactions are not understood. A quantitative understanding of the energetics and mechanism are necessary to improve processess involving of phase-transfer catalyzed N-alkylations of amides.

PTC CHARACTERISTICS

Phase-transfer catalytic systems are characterized by the presence of at least two phases and at least one interfacial region separating the phases. PTC facilitates reactions by bringing reactants into the same reaction zone, region or locale. The reaction zone may be a fluid, solid or the interfacial region between phases.[1]

The catalyst is distributed to some extent in more than one region, so it is able to move from phase to phase in order to transport reactants and products.

There are several types of phase transfer catalytic systems. Liquid-liquid phase transfer catalysis is the most common system. A liquid-liquid phase system usually consists of an aqueous phase and an immiscible organic phase. See Figure 1.

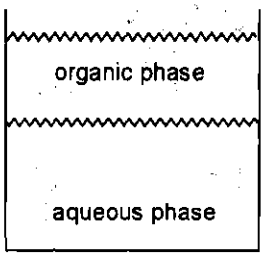


Figure 1. Liquid-liquid phase system

The solid-liquid system usually consists of an organic phase and a solid salt phase. An example would be sodium hydroxide pellets in benzene. See Figure 2.

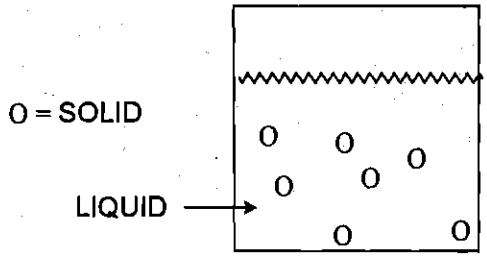


Figure 2. Solid-Liquid Phase System

Most recently, Liotta and Eckert have demonstrated the first example of solid-supercritical fluid PTC. In this case supercritical CO_2 was used as fluid phase and sodium bromide the solid phase.[6] See Figure 3.

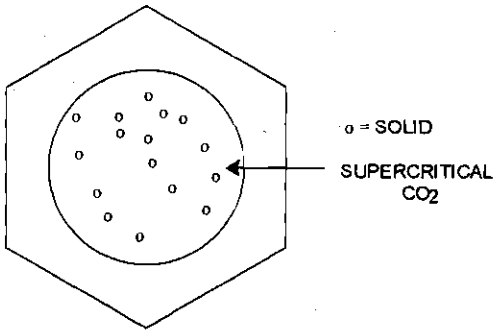


Figure 3. Solid-supercritical fluid phase system.

PTC reactions are often characterized by high yields, high selectivity, fast rates of reaction, low reaction temperatures, less exotic or more desirable solvents and ,in some cases, avoiding less toxic or hazardous reactants. PTC provides an environmentally benign way of carrying out reactions, harmful and costly wastes are dramatically reduced. For instance, it may be possible to replace benzene, DMSO, carbon tetrachloride or methylene chloride with ethyl acetate or THF. An example of hazardous solvent replacement is using supercritical CO_2 as a benign solvent in PTC reactions. Accordingly, in some reactions it may be possible to replace NaH (explosive in some solvents) with KOH or K_2CO_3.

In order for PTC to operate, the catalyst must be able to (1) exist in both phases to some extent, (2) activate one of the reagents via a substitution reaction, and (3) transport the activated reagent from its normal phase into the phase of the second

reagent in order for the desired reaction to take place. The catalyst is regenerated and the process begins again.

Many reactions between organic substrates and inorganic reagents have been facilitated in this manner. The following reactions can be carried out using PTC: displacements involving anions, catalytic hydrogenations involving gaseous hydrogen, catalytic oxidations involving molecular oxygen or permanganate, carbonylations involving carbon dioxide, deprotonations, hydrolyses and polymerizations.

Figure 4 describes how a phase-transfer catalyst (Q^+X^-) facilitates a cyanide displacement reaction in a liquid-liquid phase system consisting of an organic phase and an aqueous phase.[7] In the figure below the first step is the reversible formation of Q^+CN^- from Q^+X^-. The quarternary ammonium halide (Q+) transports the cyanide from the aqueous phase across the interface into the organic phase. The quarternary ammonium cyanide and the alkyl halide react irreversibly to form the alkyl cyanide and quarternary ammonium halide. The quarternary ammonium halide translocates to the aqueous phase where it is again available to form quarternary ammonium cyanide.

PTC APPLICATIONS

So many reactions have been catalyzed by phase-transfer catalysts because many species can be transferred. Substitutions, alkylations, eliminations, oxidations, reduction, polymerizations, deuterium exchanges and reactions involving transition metals as cocatalysts have been exploited using PTC. Refer to Table 1 for examples.[7]

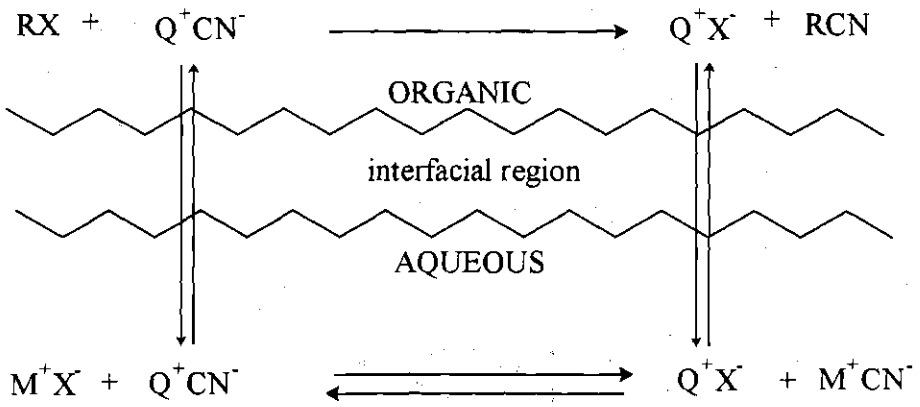


Figure 4. Generic Cyanide Displacement Reaction Catalyzed by PTC.

Just as there are many applications, there are many catalysts. Quaternary ammonium salts are by far the most generic and widely used; however, there are also quaternary phosphonium salts, crown ethers, polyethers, podands and cryptands to name a few. Figure 5 shows the distinguishing functional groups that categorize each of the molecules used as phase-transfer catalysts.

Table 1. Reactions that have utilized PTC techniques.

Reaction Type	Species Transferred or Reacted
Substitutions	CN^-, SCN^-, CNO^-, F^-, Cl^-, Br^-, I^-, N_3^-, SH^-,HSO_3^-, RS^-, RO^-, ArO^-, RCO_2^-
C-alkylations	nitriles, ketones, esters, nitro-compounds, cyclopentadienes
N-alkylations	imides, amides, sulfonamides, heterocyclic N-compounds
Oxidations	MnO_4^-, OCl^-, H_2O_2, O_2, IO_4^-, HNO_3
Reductions	BH_4^-, AlH_4^-, HCO_2^-
Transition metal mediated	carbonylation, carboxylation, hydrogentation

There are many catalysts and applications, so selecting the proper catalyst may prove difficult. The criteria for selecting a phase-transfer catalyst include structure-activity relationships, stability, catalyst separation, cost, toxicity, availability, recycle and waste treatment. The main criteria for catalyst selection depends on the application.

PTC MECHANISM

For the purpose of this kinetic study, only structure-activity relationships and stability are considered. Two steps are important in any phase-transfer catalyzed reaction. One is the transfer step and the other is the organic phase reaction step. The structure of the catalysts can have dramatic effects on the rate of transfer and on the rate of the organic phase reaction. It is also important to consider the stability of the catalyst under the reaction conditions.

The transfer step is defined as (1) the transfer of the quaternary ammonium salt from the organic to the aqueous phase, (2) the exchange of anions and (3) the transfer of the quaternary ammonium salt from the aqueous phase to the organic phase. Therefore, the transfer rate is not just the transfer of the anion, but the net anion transfer.[1]

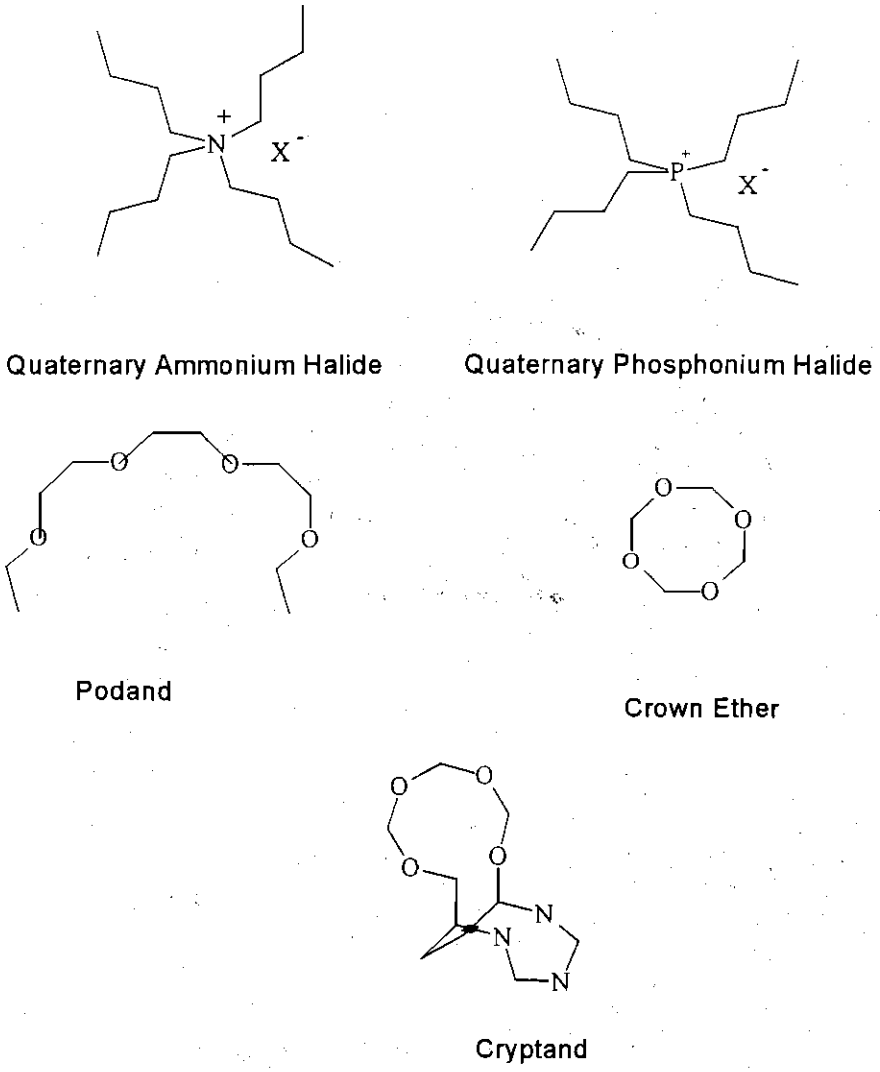


Figure 5. Molecules that have been used as Phase-Transfer Agents

After the anion transfer, the organic phase reaction or the intrinsic reaction can take place. The intrinsic reaction is defined as the sequence of reactions in the organic phase starting with the transferred anion which results in formation of product.

When the rates of transfer and the intrinsic reaction rates are equal, the transferred anion reaches a steady state concentration. If one of the steps is substanitally slower than the other, the reaction rate will approximate the rate of the slower step. However, it is often desirable to speed up a reaction.

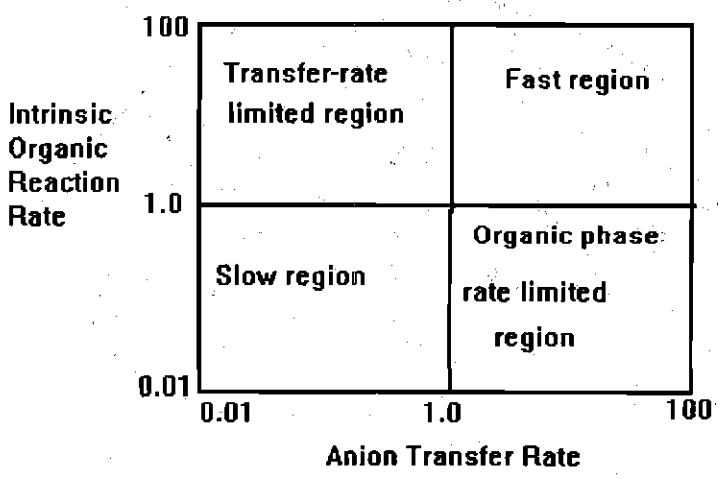


Figure 6. PTC Rate Matrix

It is important to consider whether a reaction will be transfer limited or intrinsic reaction rate limited to choose the proper catalyst for the most efficient reaction. Refer to the PTC rate matrix in Figure 6. There are four regions in the PTC rate matrix that are consistent with four scenarios.

In the intrinsic rate limited region (lower right corner) transfer rate is fast; however, intrinsic reaction rate is slow. In order to speed up the overall reaction rate,

the rate of the organic phase reaction must be increased. This can be done by using large bulky quaternary salts such as tetrabutyl-, tetrapentyl- or tetrahexylammonium halides. See Figure 7 for the structure of these catalysts.

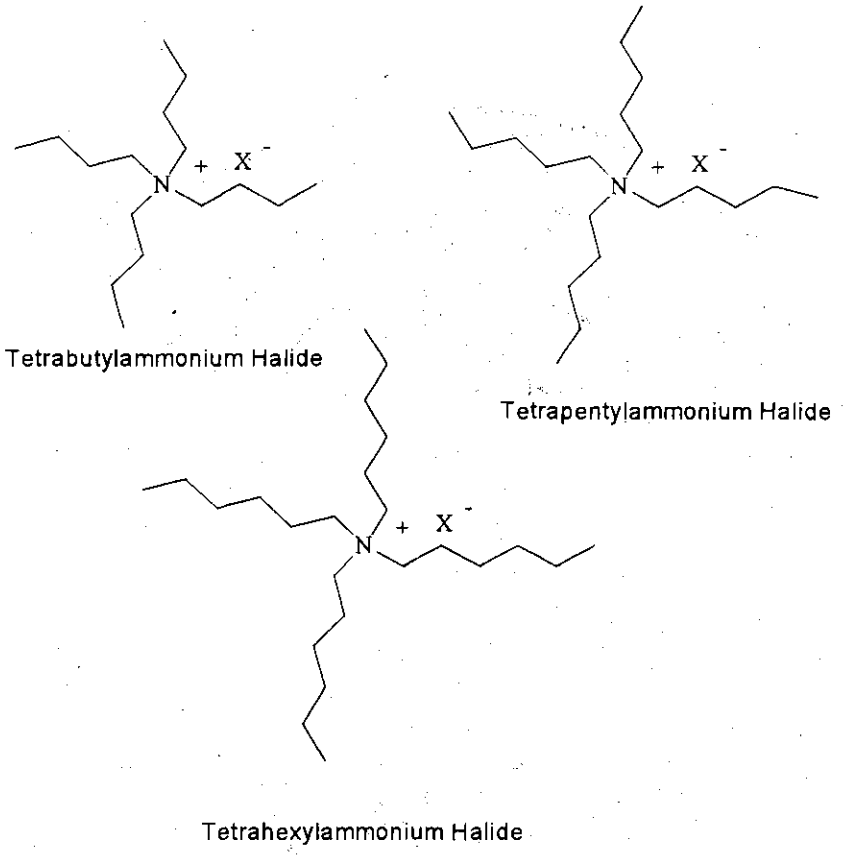
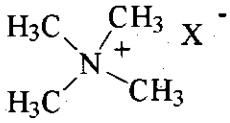


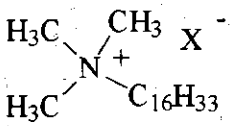
Figure 7. Bulky Quarternary Ammonium Salts

In the transfer rate limited region (upper left corner) transfer is slow, so the rate of the transfer step must be increased. This can be accomplished by using accessible quaternary salts such as hexadecyltrimethyl-, tetramethyl- or benzyltriethylammonium halides. See Figure 8 for the structure of these catalysts.

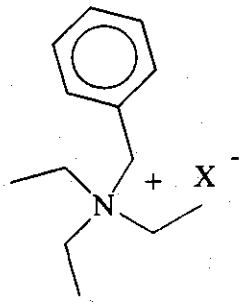
Rate can also be increased by increasing agitation. Agitation increases the interfacial area between the organic and aqueous phases. Therefore increasing agitation will increase the rate of transfer. The transfer Refer to Figure 10 for an



Tetramethylammonium Halide



Hexadecyltrimethylammonium Halide



Benzyltriethylammonium Halide

Figure 8. Accessible Quarternary Ammonium Salts.

example of increasing rate with increasing agitation rate. However, when transfer rate substantially exceeds intrinsic reaction rate, the PTC process will be independent of agitation rate.

In the fast region, both transfer rate and reaction rate are high. In this case almost any catalyst is a good choice. In the slow region, however, both transfer rate and reaction rate are slow. Many conditions may serve to speed up reactions of this type. Using two catalysts (one to speed up transfer and one to speed up the intrinsic reaction) may speed up the overall rate of reaction. Also changing temperature, water content, solvent or agitation could serve to optimize the system.

CHAPTER II

INSTRUMENTATION, REACTION SYSTEMS & EXPERIMENTAL

INSTRUMENTATION

Gas-liquid chromatography was performed on a Varian Aerograph 1400 Chromatograph. The chromatograph is equipped with an FID detector and a 10 m X 0.58 mm DB1 capillary column. A splitter was installed on the chromatograph with a 50:1 split ratio. The carrier gas was helium.

Gas-liquid chromatography was also performed on a Hewlett Packard 6890 Chromatograph. The chromatograph is equipped with an FID detector and a 30 m X 0.25 mm HP-5 5% Phenyl Methyl Siloxane capillary column. The chromatographs were executed in splitless mode. The carrier gas was helium.

^{1}H NMR (300 MHz) were recorded on a Varian Gemini 300 in DMSO solutions. Proton shifts are reported in parts per million.

REACTION SYSTEMS

All PTC reactions were carried out using a 500 mL three-neck round bottom flasks equipped with a condenser, thermometer and an overhead mechanical stirrer.

Heating was achieved by immersing the round bottom flask in an oil bath. From the neck that housed the thermometer during the reaction samples were taken via a 2 mL syringe.

The motor was a T Line Stirrer (constant speed). The motor was connected to a variac that further controlled its speed. All experiments were done with a speed of 840 $\pm$ 20 rpm. The speed of the stirrer was monitored by a stroboscope.

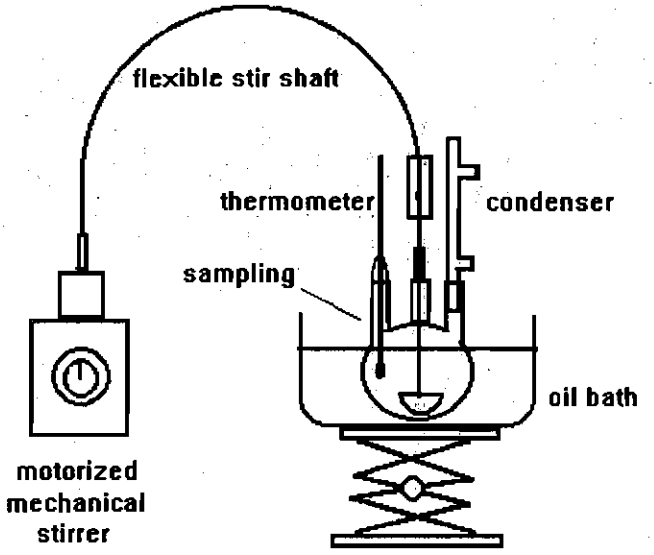


Figure 2-1. Apparatus for Kinetic Experiments.

EXPERIMENTAL

Table 2-1. Response Factors and GC Conditions.

Internal Standard	Compound (response factor)*	Column Temp, °C	Detector Temp, °C	Injector Temp, °C
$C_{16}H_{34}$	Acetanilide (3.33)	120	320	220
$C_{16}H_{34}$	NPBA (1.53)	120	320	220
$C_{16}H_{34}$	tri-n-octylamine (1.56)	190	320	190
$C_{10}H_{18}$	tri-n-butylamine (1.04)	90	320	120
C_8H_{17}	triethylamine (1.42)	50	70	320
$C_{16}H_{34}$	Acetanilide (2.74)#	80	300	250
$C_{16}H_{34}$	NPBA (1.34)#	80	300	250

- Response factor relative to internal standard using Varian Aeroscope 1400 Series GC. All compounds were obtained from Aldrich except NPBA which was synthesized. The internal standard was hexadecane.

\# Response factor relative to internal standard using Hewlett Packard 6890 Series GC.

Synthesis of NPBA: Acetylation of N-phenyl-N-benzylamine.

To a clean, dry 250 mL round bottom flask, 100 mL of methylene chloride was added. The flask was placed in a dry ice bath (CO_2/Acetone). A stir bar was added then 5.0 g of N-phenyl-N-benzylamine (0.027 moles) was added and followed by 5.454 g of triethylamine (0.054 moles) which was followed by 3.305 g of acetic anhydride. The reaction was allowed to reach ambient temperature.

The solvent was removed under reduced pressure via vacuum distillation. The crude mixture was taken up in 50 mL of methylene chloride. To this solution, 10 drops of concentrated HCl was added. A white precipitate formed and was separated by gravity filtration. The solvent was removed using a rotovap.

A H^1 NMR was taken: (3H), s, 1.8 ppm, (2H), s, 4.87 ppm, (10H), m, 7.1-7.4 ppm.

General Procedures for the Kinetics of the N-phenyl-N-benzylacetamide Formation under Solid-Liquid Conditions

To a clean, dry 500 mL round bottom flask acetanilide was added. Afterwards o-dichlorobenzene was added and was followed by as an internal standard (See Table 3) and potassium hydroxide. The resulting solid-liquid phase mixture was stirred at 840($\pm$20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized. At this point, agitation was arrested and tetra-n-butylammonium chloride hydrate was added and followed with agitation. After dissolution of the tetra-n-

butylammonium chloride hydrate, freshly distilled benzyl chloride was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas liquid chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 1 mL of o-dichlorobenzene.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence and Absence of 10.% Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was added and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via

syringe and dissolved in 1 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken, placed in an acetone/dry ice bath, and transferred to the GC vial rack (cooled to 5°C) from which they were analyzed via an autosampler.

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Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene / H_2O (100/0.50) in the Presence and Absence of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

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To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.90 g of hexadecane (0.013 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was added, followed by 0.50 mL of water added via syringe and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

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Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene / H_2O (100/1.00) in the Presence and Absence of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was added, followed by 1.00 mL of water added via syringe and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via

syringe and dissolved in 1 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken, placed in an acetone/dry ice bath, and transferred to the GC vial rack (cooled to 5°C) from which they were analyzed via an autosampler.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene / H_2O (100/1.00) in the Presence and Absence of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was added, followed by 1.00 mL of water added via syringe and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 1 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken,

placed in an acetone/dry ice bath, and transferred to the GC vial rack (cooled to 5°C) from which they were analyzed via an autosampler.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene / H_2O (100/0.15) in the Presence and Absence of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was added, followed by 0.15 mL of water added via syringe and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 1 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken,

placed in an acetone/dry ice bath, and transferred to the GC vial rack (cooled to 5°C) from which they were analyzed via an autosampler.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene / H_2O (100/0.15) in the Presence and Absence of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was added, followed by 0.15 mL of water added via syringe and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 1 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken,

placed in an acetone/dry ice bath, and transferred to the GC vial rack (cooled to 5°C) from which they were analyzed via an autosampler.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 5 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 0.71 g of tetra-n-butylammonium chloride hydrate (0.0026 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.75, 1.25, 1,75, 2.25, 2.75, 3.25, 3.75, 4.25, 5.25, 6, 7.02, 8, 9, 10.02, 13, 20, 30, 35, 40, 45, 50 minutes samples were taken.

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was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 0.36 g of tetra-n-butylammonium chloride hydrate (0.0013 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 45, 75, 105, 135, 166.2, 195, 225, 255, 285, 315, 360, 421.2, 480, 540, 601.2, 780, 900, 1200, 1500, 1803, 2106, 2400, 2700, 3000 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 1 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point,

agitation was arrested and 0.14 g of tetra-n-butylammonium chloride hydrate (0.00052 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 45, 75, 105, 135, 180, 241.8, 300, 420, 600, 900, 1200, 1500, 1800, 2400, 3000, 3600, 4800, 7227, 10800 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence 1.0 M Acetanilide and of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 13.8 g of acetanilide (0.10 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 0.14 g of tetra-n-butylammonium chloride hydrate (0.00052 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium

chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence 1.0 M Acetanilide and of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 13.8 g of acetanilide (0.10 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 0.14 g of tetra-n-butylammonium chloride hydrate (0.00052 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via

syringe and dissolved in 2 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence 0.25 M Acetanilide and of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 3.45 g of acetanilide (0.025 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 0.14 g of tetra-n-butylammonium chloride hydrate (0.00052 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence 1.53 M Acetanilide and of 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 21 g of acetanilide (0.153 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 0.14 g of tetra-n-butylammonium chloride hydrate (0.00052 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0, 15, 40, 65, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.0102 Moles KOH and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 0.57 g of potassium hydroxide (0.0102 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.333, 0.667, 1.085, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.102 Moles of KOH and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051

moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 5.70 g of potassium hydroxide (0.102 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.083, 1.5, 2, 2.5, 3, 4, 7, 10, 15, 20, 26.5, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.102 Moles KOH and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.90 g of hexadecane (0.013 moles, 99% pure, Aldrich) as an internal standard and 5.70 g of potassium hydroxide (0.102 moles).

The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.08, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.0051 Moles KOH and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 0.29 g of potassium hydroxide (0.0051 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium

chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.081, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.0051 Moles KOH and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 0.57 g of potassium hydroxide (0.0051 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via

syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.081, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 46.5, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.208 Moles of Benzyl Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.005 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 26.00 g of freshly distilled benzyl chloride (0.208 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.082, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.208 Moles of Benzyl Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 26.00 g of freshly distilled benzyl chloride (0.208 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.082, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.0416 Moles of Benzyl Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene

was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 52.00 g of freshly distilled benzyl chloride (0.416 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.082, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.0416 Moles of Benzyl Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point,

agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 52.00 g of freshly distilled benzyl chloride (0.416 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.082, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.204 Moles of Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.90 g of hexadecane (0.013 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 8.76 g of potassium chloride (0.204 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly

distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.081, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.051 Moles of Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 3.77 g of potassium chloride (0.051 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At

designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.083, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.00137 Moles of Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 0.1014 g of potassium chloride (0.00137 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.082, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.051 Moles of Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 3.77 g of potassium chloride (0.051 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.083, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.00137 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 0.10 g of potassium chloride (0.00137 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.75, 1.25, 1.75, 2.15, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.00137 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 0.10 g of potassium chloride (0.00137 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.75, 1.25, 1.75, 2.25, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 36, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.051 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 3.77 g of potassium chloride (0.051 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.08, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.051 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 3.77 g of potassium chloride (0.051 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.08, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.204 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 15.10 g of potassium chloride (0.204 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.667, 1.083, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.204 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 15.10 g of potassium chloride (0.204 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.08, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 0.204 Moles of Anhydrous Potassium Chloride and 10 % Tetra-n-butylammonium Chloride Hydrate at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard, 3.03 g of potassium hydroxide (0.054 moles) and 15.10 g of potassium chloride (0.204 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.42 g of tetra-n-butylammonium chloride hydrate (0.0051 moles) was and followed with agitation. After dissolution of the tetra-n-butylammonium chloride hydrate, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 0.25, 0.667, 1.08, 1.5, 2, 2.5, 3, 4, 5, 7, 10, 15, 25, 35, 45, 60 minutes samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Tetra-n-octylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene

was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 2.79 g of tetra-n-octylammonium bromide (0.0051 moles) was added and followed with agitation. After dissolution of the tetra-n-octylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Tetra-n-octylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point,

agitation was arrested and 2.79 g of tetra-n-octylammonium bromide (0.005 moles) was added and followed with agitation. After dissolution of the tetra-n-octylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Tetra-n-heptylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 2.5030 g of tetra-n-heptylammonium bromide (0.0051 moles) was added and followed with agitation. After dissolution of the tetra-n-heptylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Tetra-n-heptylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 2.5030 g of tetra-n-heptylammonium bromide (0.0051 moles) was added and followed with agitation. After dissolution of the tetra-n-heptylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via

syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Tetraethylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.072 g of tetraethylammonium bromide (0.0051 moles) was added and followed with agitation. After dissolution of the tetraethylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Tetraethylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.072 g of tetraethylammonium bromide (0.0051 moles) was added and followed with agitation. After dissolution of the tetraethylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Benzytrimethylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure,

Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.174 g of benzyltrimethylammonium bromide (0.0051 moles) was added and followed with agitation. After dissolution of the benzyltrimethylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Benzytrimethylammonium Bromide at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 1.0742 g of benzyltrimethylammonium bromide (0.005

moles) was added and followed with agitation. After dissolution of the benzyltrimethylammonium bromide, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Aliquat 336 at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840(±20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 2.06 g of aliquat 336 (0.0051 moles) was added and followed with agitation. After dissolution of the aliquat 336, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

Kinetics of N-phenyl-N-benzylacetamide Formation in o-Dichlorobenzene in the Presence of 10 % Aliquat 336 at 78 °C

To a clean, dry 500 mL round bottom flask 6.89 g of acetanilide (0.051 moles, 97 % pure, Aldrich) were added. Afterwards, 100 mL of o-dichlorobenzene was added which was followed by 2.24 g of hexadecane (0.010 moles, 99% pure, Aldrich) as an internal standard and 3.03 g of potassium hydroxide (0.054 moles). The resulting solid-liquid phase mixture was stirred at 840($\pm$20) rpm with a high speed overhead mechanical stirrer until the temperature stabilized at 78 °C. At this point, agitation was arrested and 2.06 g of aliquat 336 (0.0051 moles) was added and followed with agitation. After dissolution of the aliquat 336, 13.20 g of freshly distilled benzyl chloride (0.104 moles) was added. Immediately after the addition of the benzyl chloride, agitation and timing began.

The progress of the reaction was monitored via gas chromatography. At designated times ca 0.1 mL of reaction mixture was taken out of the reaction via syringe and dissolved in 2 mL of tetrahydrofuran. At 15, 40.02, 64.92, 90, 120, 150, 180, 240, 300, 420, 600, 900, 1200, 1500, 2100, 2700, 3600 seconds samples were taken.

CHAPTER III

RESULTS AND DISCUSSION

MECHANISM & KINETIC DESCRIPTION

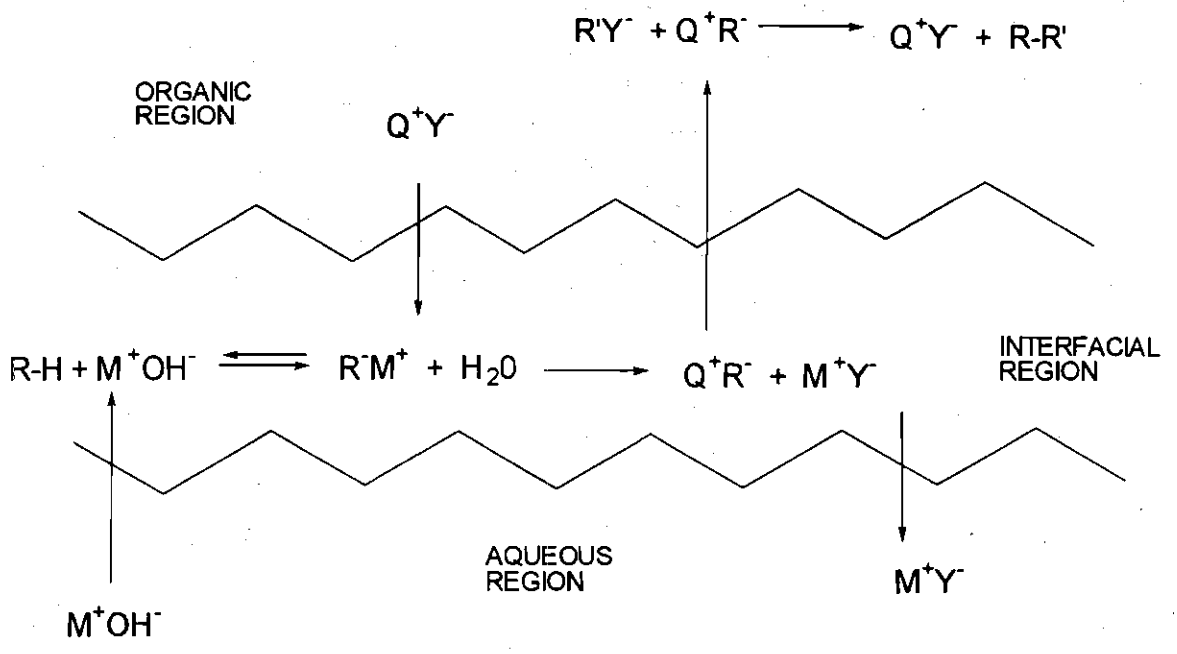
There are several types of phase-transfer catalytic systems. Liquid-liquid phase transfer catalysis is the most common system. It consists of an aqueous phase and an immiscible organic phase. Three general mechanisms have been proposed to account for the observations encountered in liquid-liquid PTC reactions involving hydroxide ions; the Starks Extraction Mechanism, the Makosza Interfacial Mechanism, and the Modified Interfacial Mechanism.

In the Starks Extraction Mechanism the phase-transfer catalyst distributes the hydroxide ion between the liquid and organic phases (See Figure 4). No reaction occurs in the interfacial region . The phase-transfer cation transfers the ion from the aqueous phase through the interfacial region into the organic phase where it is available to deprotonate an organic acid, RH. The resulting organic anion reacts with the electrophilic reagent, R'Y in the organic phase. The resulting substitution reaction produces the product RR' and the phase-transfer salt Q^+Y^-. The sequential phase-transfer salt then transports the leaving group (Y^-) across the interfacial region into the aqueous phase.

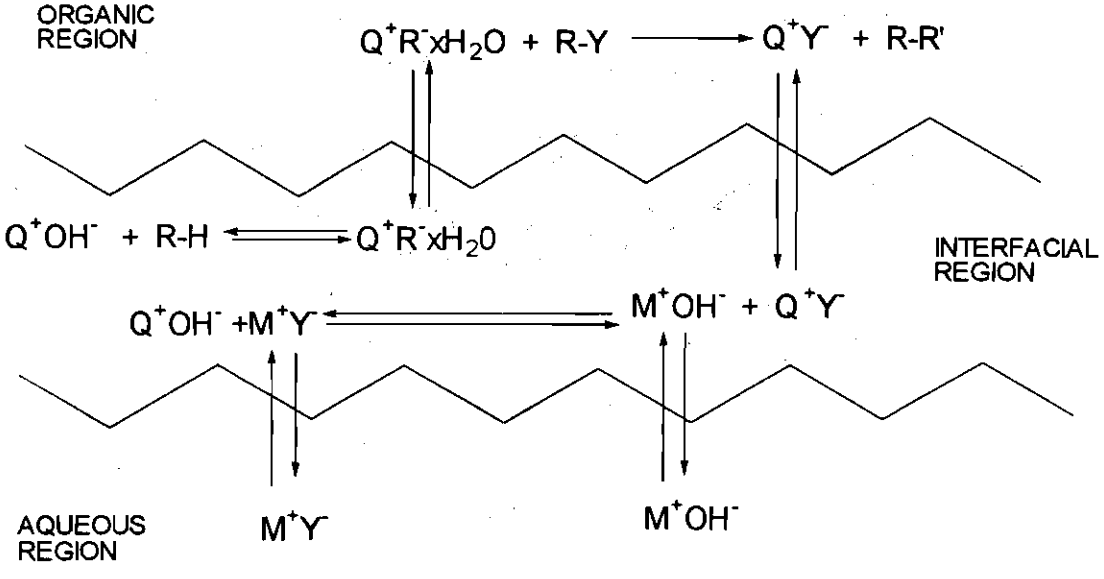
The transfer of OH^- is expected to be energetically more difficult than other commonly encountered leaving group anions like Cl^-, Br^- and I^- because it has a higher

charge-to –volume ratio and is highly solvated by water and would rather remain in the aqueous phase. In fact, extraction experiments reveal that in a phenylacetonitrile / 50 % NaOH two-phase system, more than 99 % of the benzyltriethylammonium ion is associated with the chloride ion rather than the hydroxide ion. This would suggest that reaction would be slow when using catalytic amounts of the quaternary ammonium salt; however, this is not observed.[1]

It is for this reason that Makosza proposed the Interfacial Mechanism which suggests that the quaternary ammonium halide and the hydroxide do not initiate the reaction. The first step of the Interfacial Mechanism the hydroxide ion reacts with the organic acid in the interfacial region. Then the catalyst transports the resulting solvated carbanion from the interfacial region into the organic phase where alkylation occurs.



In the Modified Interfacial Mechanism the phase-transfer catalyst is distributed between the organic and interfacial regions. In this process instead of transporting the hydroxide from the aqueous phase to the organic phase, as proposed by Starks, the quaternary salt transports the hydroxide ion from the interfacial region to the organic phase. This could possibly result in a less drastic free energy change since the first step involves the reaction of OH^- with the phase-transfer cation halide salt at the interfacial region. This reaction produces the phase-transfer cation hydroxide pair. The second step involves the reaction of the phase-transfer cation hydroxide pair with the organic acid in the interfacial region to produce the phase-transfer cation-carbanion pair. The final step is the carbanion with the alkyl halide within the organic phase to give the product.



Another common phase-transfer catalytic system is the solid-liquid. It consists of an immiscible organic phase and small amounts of water from hydrated reactants. The Liotta Omega Phase Mechanism was proposed to determine the effect of small amounts of water on the reaction rate.[8] It is proposed that that when small amounts of water are present in solid-liquid PTC systems, the water coats the surface of the solid. This surface layer is called the omega phase. When a phase-transfer catalyst is present, the omega phase consists of catalyst, salt and water. It has been demonstrated that reaction can take place in this phase. See Figure 3-a.

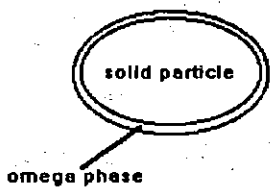


Figure 3-a. Formation of omega phase on solid salt surface.

When considering solid-liquid PTC reactions involving hydroxide, it is necessary to consider the effects of water since hydroxides are often very hydrated.

A study of the N-alkylation of acetanilide in liquid-liquid and solid-liquid PTC systems should prove very effective in developing a model for studying the characteristics of the Modified Interfacial Mechanism and the Omega Phase Mechanism. Mechanisms for the N-alkylation of acetanilide in the liquid-liquid and solid-liquid PTC

systems have been proposed. The following is the proposed mechanism for the N-alkylation of the acetanilide in the absence of a catalyst under liquid-liquid conditions:

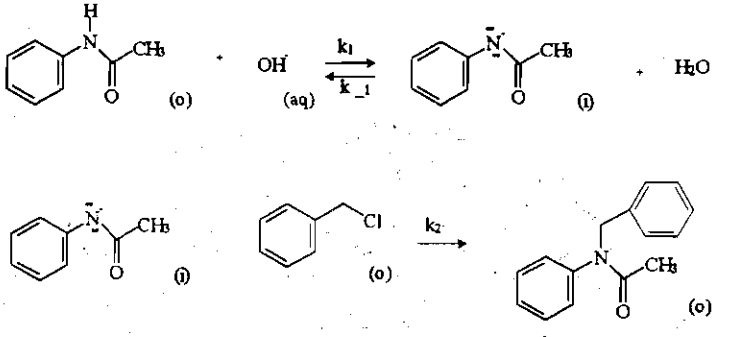


Figure 3-b. Uncatalyzed Mechanism of Deprotonation and N-alkylation of Acetanilide.
o = organic phase, i = interfacial region, aq = aqueous phase

The following is the proposed mechanism for the N-alkylation of the acetanilide in the presence of a catalyst under liquid-liquid conditions:

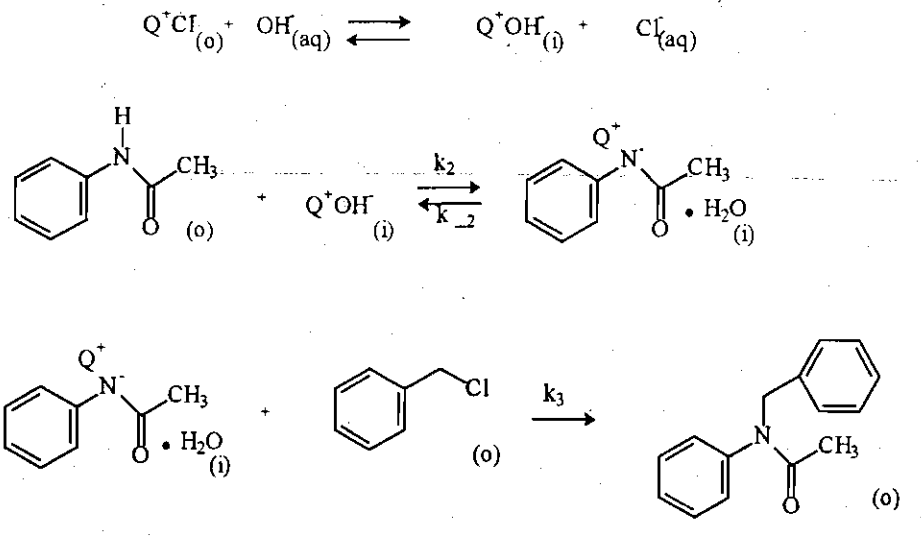


Figure 3-c. Catalyzed Mechanism for the Deprotonation and N-alkylation of Acetanilide.

o = organic phase, i = interfacial region, aq = aqueous phase

The following is the derivation of the rate expression based on the proposed mechanism for the uncatalyzed N-alkylation reaction in a liquid-liquid two phase system:

$$\frac{d[RR']}{dt} = k_2[R-]_i[R'X]_o \qquad (1.1)$$

Using the steady-state approximation, the preceding equation can be expressed in terms of reagent concentrations.

$$\frac{d[R-]_i}{dt} = k1[RH]_o[OH-]_{aq} - k_{-1}[R-]_i - k_2[R-]_i[R'X]_o \qquad (1.2)$$

$$[R-]_i = \frac{k_1[RH]_o[OH-]_{aq}}{k_{-1} - k_2[R'X]_o} \qquad (1.3)$$

$$\frac{d[RR']_o}{dt} = \frac{k_1k_2[RH]_o[R'X]_o[OH-]_{aq}}{k_{-1} - k_2[R'X]_o} \qquad (1.4)$$

Equation (1.4) is the rate expression for the uncatalyzed mechanism.

The following is the derivation of the rate expression based on the proposed mechanism for the catalyzed N-alkylation reaction in a liquid-liquid two phase system:

$$\frac{d[RR']}{dt} = k_2[Q+R-]_o[R'X]_o \qquad (2.1)$$

Using the steady-state approximation for the $[Q^+R^-]$ and $[Q^+OH^-]$, the preceding equation can be expressed in terms of reagent concentrations.

$$\frac{d[Q+R-]_o}{dt} = k_2[Q+OH-]_o[RH]_o - k_2[Q+R-]_o - k_3[Q+R-]_o[R'X]_o \quad (2.2)$$

$$\frac{d[Q+OH-]_i}{dt} = k_1[OH-]_{aq}[Q+X-]_o - k_{-1}[Q+OH-]_o[X-]_{aq} - k_2[Q+OH-]_o[RH]_o + k_{-2}[Q+R-]_o$$

(2.3)

$$\frac{d[RR']_o}{dt} = \frac{k_1k_2k_3[Q+X-]_o[OH-]_{aq}[RH]_o[R'X]_o}{k_{-1}k_{-2}[X-]_{aq} + k_{-1}k_3[R'X]_o[X-]_{aq} + k_2k_3[R'X]_o[RH]_o} \quad (2.4)$$

Equation (2.4) is the rate expression for the catalyzed mechanism under liquid-liquid PTC conditions.

Kinetics of the sl-PTC Deprotonation and N-alkylation of Acetanilide

A study of the deprotonation and N-alkylation of acetanilide in a solid-liquid PTC system has been carried out to study the characteristics of the Omega Phase Mechanism. Mechanisms for the deprotonation and N-alkylation of acetanilide in the liquid-liquid and solid-liquid PTC systems have been proposed. Recall Figures 3-a and 3-b. Activation energies determined for the deprotonation and N-alkylation of acetanilide with potassium hydroxide and benzyl chloride in the presence and absence of catalyst under liquid-liquid conditions indicate that the uncatalyzed reaction is mass transfer limited whereas the catalyzed reaction is reaction rate limited.[9]

A series of experiments were conducted in order to ascertain whether the deprotonation and N-alkylation of acetanilide is reaction rate transfer rate limited or reaction rate limited under solid-liquid conditions. If the reaction is mass transfer limited, each encounter between individual molecules would lead to reaction. When this occurs, the activation energy is about 1 kcal / mole.

Using the Arrhenius relationship:

$$k_{obs} = Ae^{-Ea/RT},$$

a plot of *lnk* versus 1/T, the activation energy, E_a, can be gleaned. Further, since k_{obs} is directly related to initial rate of reaction, a plot of ln(rate) versus 1/T should yield the activation energy.

Recall Figure 3-b and see equation 4.4 below. From the proposed mechanism and resulting rate expression the presence of an omega phase and the efficacy of the mechanism was probed.

The following is the derivation of the rate expression based on the proposed mechanism for the catalyzed N-alkylation reaction in a solid-liquid two phase system in which an omega (ω) phase is involved:

$$\frac{d[RR']}{dt} = k_2[Q^+R^-]_o[R'X]_o \quad (3.1)$$

Using the steady-state approximation for the $[Q^+R^-]$ and $[Q^+OH^-]$, the preceding equation can be expressed in terms of reagent concentrations.

$$\frac{d[Q+R-]_o}{dt} = k_2[Q+OH-]_\omega[RH]_o - k_2[Q+R-]_o - k_3[Q+R-]_o[R'X]_o \qquad (3.2)$$

$$\frac{d[Q+OH-]_\omega}{dt} = k_1[OH-]_{aq}[Q+X-]_o - k_{-1}[Q+OH-]_\omega[X-]_{aq} - k_2[Q+OH-]_\omega[RH]_o + k_{-2}[Q+R-]_o \qquad (3.3)$$

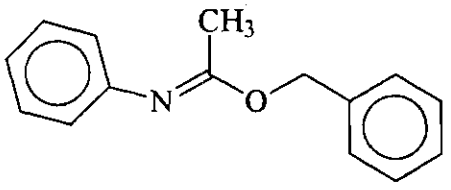
$$\frac{d[RR']_o}{dt} = \frac{k_1k_2k_3[Q+X-]_o[OH-]_{aq}[RH]_o[R'X]_o}{k_{-1}k_{-2}[X-]_{aq} + k_{-1}k_3[R'X]_o[X-]_{aq} + k_2k_3[R'X]_o[RH]_o} \qquad (3.4)$$

Equation (3.4) is the rate expression for the catalyzed mechanism under liquid-liquid conditions.

The Effect of Added Water on Initial Rate of N-benzylation of Acetanilide.

In developing a model for the the N-benzylation of acetanilide it was important to determine the effect of added water on the initial rate of reaction. This is especially important for the proposed Liotta Omega Phase Mechanism. The data from these experiments is presented in Figures and Tables 3-1 to 3-9. The data shows that the reaction rate increases with the addition of water. This postulate suggests that upon addition of water and after equilibration of the system, the quaternary ammonium salt is translocated onto the surface of the salt. This phase consists of water, dissolved base, o-dichlorobenzene, and quaternary ammonium salt.[8]

Also, in the presence of small amounts of water Product (2) has been observed.



Product (2)

Product (2) is formed via alkylation of the ambident acetanilide anion produced by deprotonation of acetanilide. If an omega phase is intimately involved in the rate enhancement, a more polar media is involved which could lower the activation energy of the reaction path leading to the Product (2). So, this data indicates that the omega phase is involved in the rate enhancement of NPBA, and it also enhances the rate of Product (2) formation. The formation of the O-alkylated product is only observed in the presence of water, and the conversion of acetanilide to Product (2) was only observed to reach ca 1 %. This equates to a selectivity ratio of about 100:1 [NPBA:Product (2)] or a difference in ΔG of circa 11 kcal/mole for the two reaction paths.

The Effect of Varying TBAC Concentration on Initial Rate of N-benzylation of Acetanilide.

The initial rate of reaction was monitored while increasing the concentration of TBAC. The data from these experiments is shown in Figures and Tables 3-10 to 3-14. The data indicates that as the amount of TBAC increases the initial rate increases. This is consistent with the mechanism; yet the slope in Figure 3-10 decreases as the concentration of TBAC increases. This indicates that the catalyst may degrade under the reaction conditions.

The Effect of Varying Moles of KCl on Initial Rate of N-benzylation of Acetanilide.

Further probing of the mechanism shows a decrease in initial rate of reaction with addition of anhydrous KCl. The data of these experiments is found in Figures and Tables 3-15 to 3-21. According to the mechanism, addition of Cl^- should shift the initial equilibrium constant K_1 (representing k_1/k_{-1}) so that less Q^+OH^- is formed. When the steady state concentration of Q^+OH^- is much less, the rate of the reaction is decreased.

However, when comparing the addition of 0.00137 moles of anhydrous KCl with no addition of anhydrous KCl, the rate increases. Since the rate increases upon addition of anhydrous KCl, then decreases as more KCl is added, the anhydrous KCl seems to activate the Q^+OH^-. This can be explained by dehydration of the Q^+OH^-, and the less solvated Q^+OH^- in the organic phase is more reactive. This behavior has been observed by Landini who suggests that the amount of water in the organic phase can be decreased by increasing the concentration of aqueous NaOH. In his work, he found that as the concentration is changed from 10 % to 50 % NaOH, the hydration of the OH^- in the organic phase is significantly abated. This decrease in hydration destabilizes or activates the Q^+OH^-.[10]

This behavior seems to be consistent with theory and the proposed mechanism. First, the initial rate of reaction increases because of hydroxide activation due to dehydration. Then the reaction rate decreases because the equilibrium shifts so that Q^+OH^- is formed in a lower steady-state concentration.

If this line of thought is correct, the addition of hydrated KCl should not increase the rate of reaction to the same extent as its hydrated counterpart but only decrease the rate of deprotonation and N-benzylation. The data from these experiments are presented in Figures and Tables 3-22 to 3-25. The data indicates that the reaction rate decreases with the addition of hydrated KCl. The addition of hydrated KCl should not drastically dehydrate the Q^+OH^- in the organic phase, so less activation should occur.

The Effects of the Amount of Hydroxide, Benzyl Chloride and Acetanilide on the Initial Rate of the N-benzylation of Acetanilide.

Additional probing of the mechanism includes monitoring the change in initial rate with the change in concentration of acetanilide, benzyl chloride and potassium hydroxide. Studies show (Figures and Tables 3-26 to 3-30) that as the amount of potassium hydroxide is increased the rate is increased.

Experiments were carried out to probe the mechanism with respect to benzyl chloride. The results (Figures and Tables 3-31 to 3-35) show that as the amount of benzyl chloride increases, the rate of reaction increases. This too is in accordance with the proposed mechanism. As the concentration of benzyl chloride increases the rate increases, yet its slope decreases. This could indicate that at higher concentrations the rate of the hydrolysis of benzyl chloride increase.

Studies (Figures and Tables 3-36 to 3-39) also indicate that as the molarity of acetanilide increases, the rate of the N-benzylation of acetanilide increases. This behavior is also consistent with the proposed mechanism.

The Effect of the Type of Catalyst on the Initial Rate of the N-benzylation of Acetanilide.

To further characterize the N-benzylation of acetanilide a series of catalysts were used. In addition to tetra-n-butylammonium chloride, tetraethylammonium bromide, tetra-n-heptylammonium bromide, tetra-n-octylammonium bromide, benzyltrimethylammonium bromide and aliquot 336 (trioctylmethylammonium bromide) were used in the reaction. From Table 3-40 it can be observed that the more accessible the catalyst, the faster the rate of reaction. In previous work[9], the reaction was found to be reaction rate limited; however, a reaction rate limited reaction should be found to be increased by bulky quaternary ammonium salts. When using hydroxide in a sl-ptc reaction, it is often difficult to transfer.[1] So, using an accessible phase-transfer agent should accelerate the transfer of hydroxide and the reaction. In fact, this is observed in Tables and Figures 3-41 to 3-50.

APPENDIX

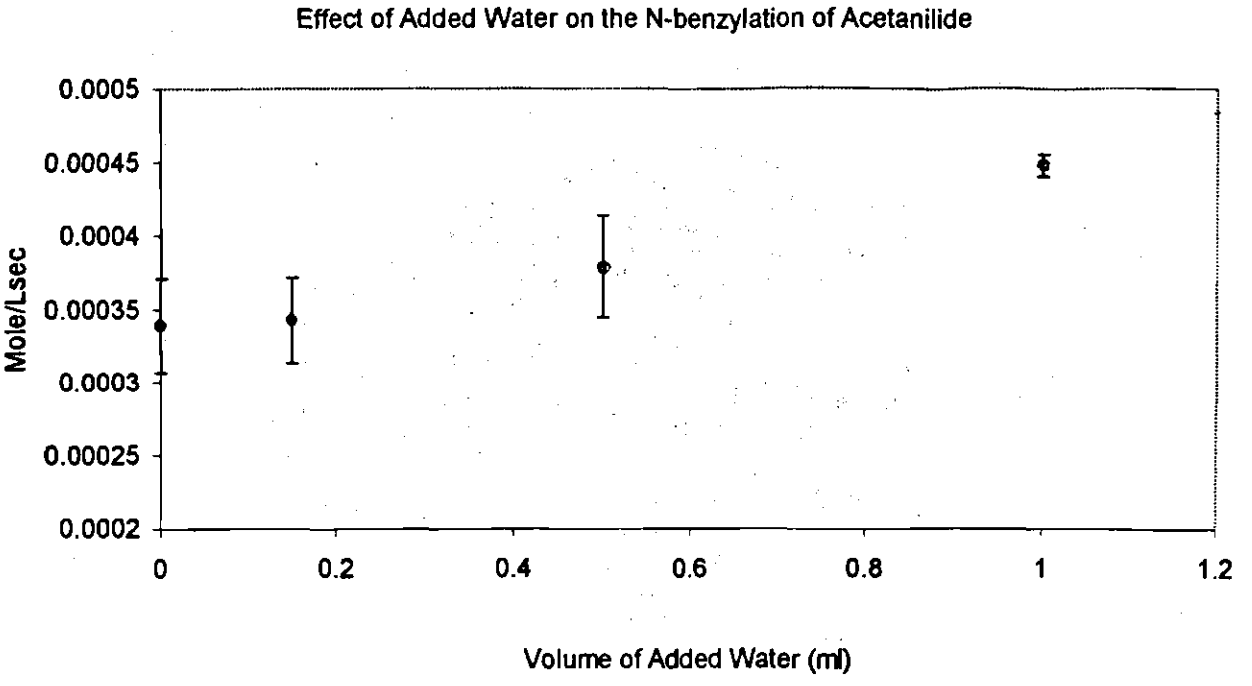


Figure 3.1. Effect of Water on the Initial Rate of the N-benzylation of Acetanilide.

Table 3.1. Effect of Water on the Initial Rate of the N-benzylation of Acetanilide

VOLUME OF WATER ADDED (ml)	INITIAL RATE (mole/Lsec)	STANDARD DEVIATION
0.00	3.39×10^{-4}	3.2×10^{-5}
0.15	3.43×10^{-4}	2.9×10^{-5}
0.50	3.79×10^{-4}	3.45×10^{-5}
1.00	4.48×10^{-4}	7.5×10^{-6}

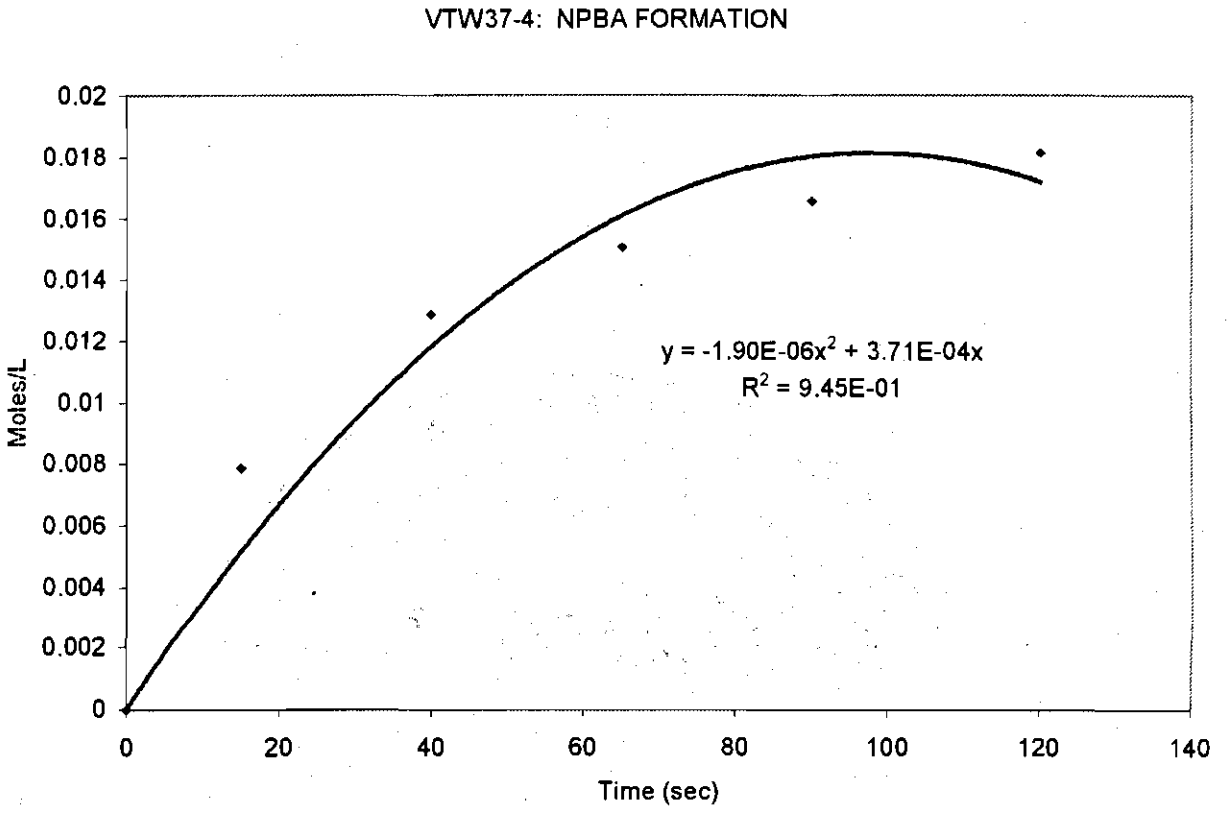


Figure 3.2. N-benzylation of Acetanilide (100ml / 0 ml: 1,2-dichlorobenzene/Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**0.0 ml Water**	0.0 moles KCl

Table 3.2. N-benzylation of Acetanilide (100 ml/ 0 ml: 1,2-dichlorobenzene/Water) at 78°C

TIME (sec)	NPBA
0.0	0.0
15	0.007
40	0.0129
65	0.0151
90	0.0166
120	0.0182
150	0.0203
180	0.0217
240	0.0251
300	0.0287
420	0.0336
600	0.0394
900	0.0443
1200	0.0454
1500	0.0456

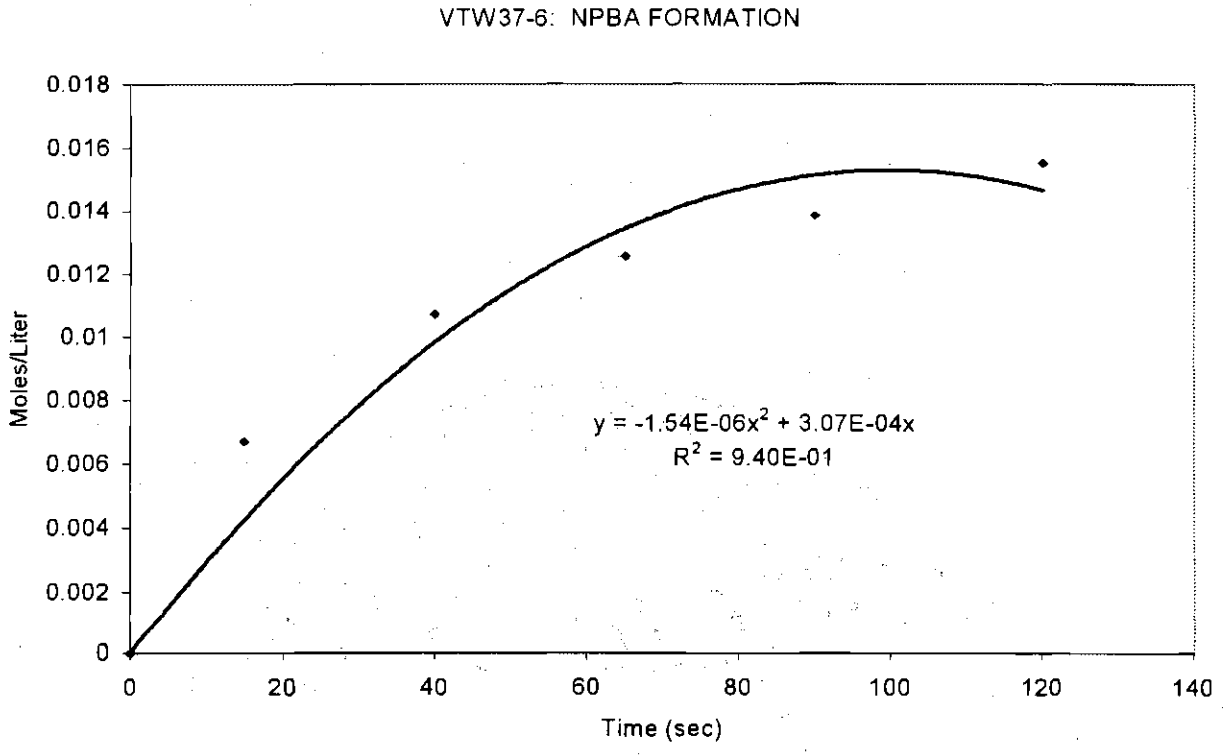


Figure 3.3. N-benzylation of Acetanilide (100ml / 0 ml: 1,2-dichlorobenzene/Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**0.0 ml Water**	0.0 moles KCl

Table 3.3. N-benzylation of Acetanilide (100ml / 0 ml: 1,2-dichlorobenzene/Water) at 78°C.

TIME (sec)	NPBA
0	0.0
15	0.0067
40	0.0107
65	0.0126
90	0.0139
120	0.0155
150	0.0172
180	0.0189
240	0.0224
300	0.0262
420	0.0329
600	0.0404
900	0.0458
1200	0.0471
1500	0.0473
2100	0.0477

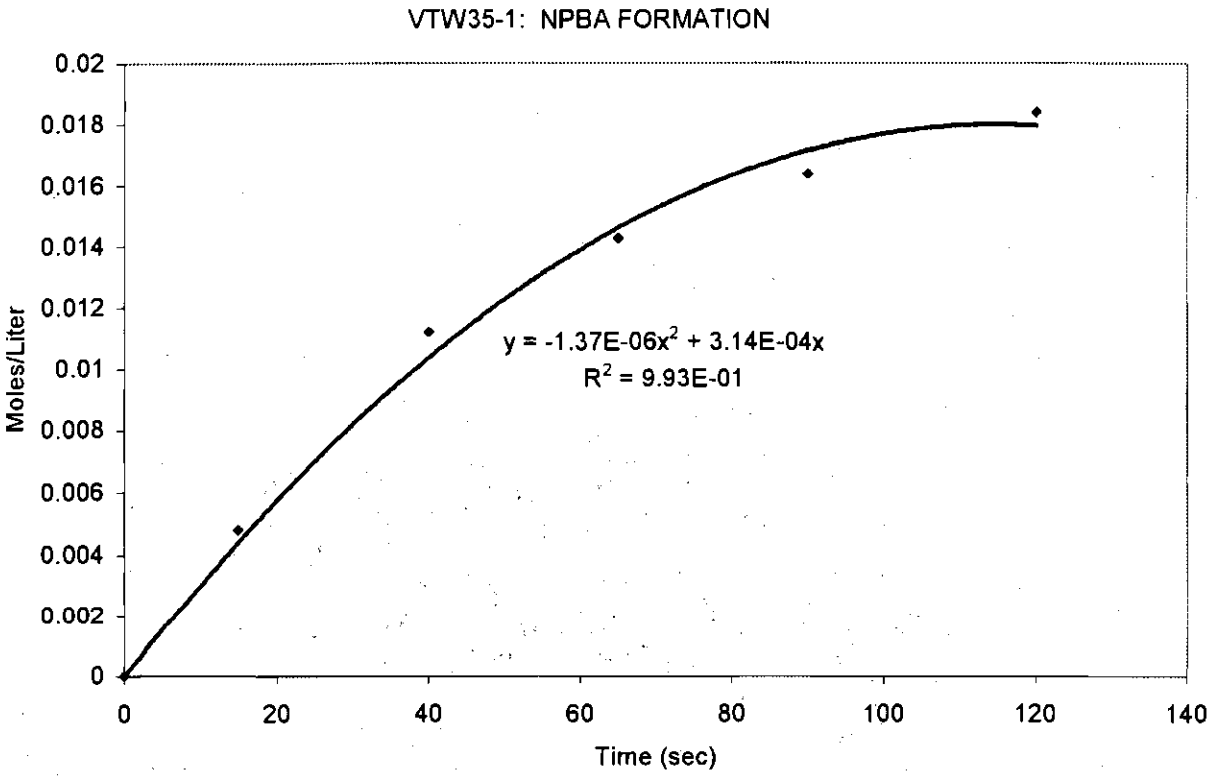


Figure 3.4. N-benzylation of Acetanilide (100ml / 0.15 ml: 1,2-dichlorobenzene/ Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**0.15 ml Water**	0.0 moles KCl

Table 3.4. N-benzylation of Acetanilide (100ml / 0.15 ml: 1,2-dichlorobenzene/ Water) at 78°C.

TIME (sec)	NPBA
0	0
15	0.0048
40	0.0112
65	0.0142
90	0.0164
120	0.0183
150	0.0204
180	0.0224
240	0.0292
300	0.0259
420	0.0337
600	0.0392
900	0.0431
1200	0.0443
1500	0.0447
2100	0.0448
2700	0.0447
3600	0.0446

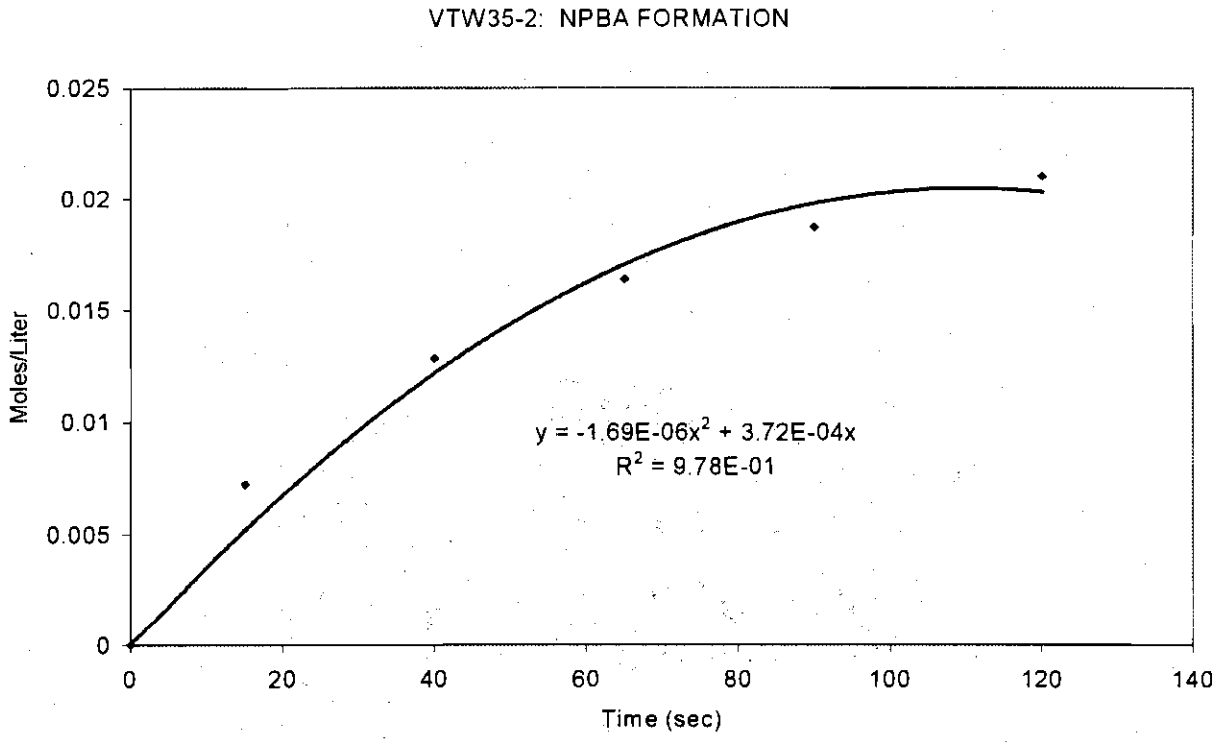


Figure 3.5. N-benzylation of Acetanilide (100ml / 0.15 ml: 1,2-dichlorobenzene/ Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78oC	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**0.15 ml Water**	0.0 moles KCl

Figure 3.5. N-benzylation of Acetanilide (100ml / 0.15 ml: 1,2-dichlorobenzene/ Water) at 78°C.

TIME (sec)	NPBA
0	0.0
15	0.0072
40	0.0128
65	0.0164
90	0.0187
120	0.0210
150	0.0231
180	0.0251
240	0.0287
300	0.0316
420	0.0361
600	0.0407
900	0.0438
1200	0.0446
1500	0.0450
2100	0.0452
2700	0.0456
3600	0.0456

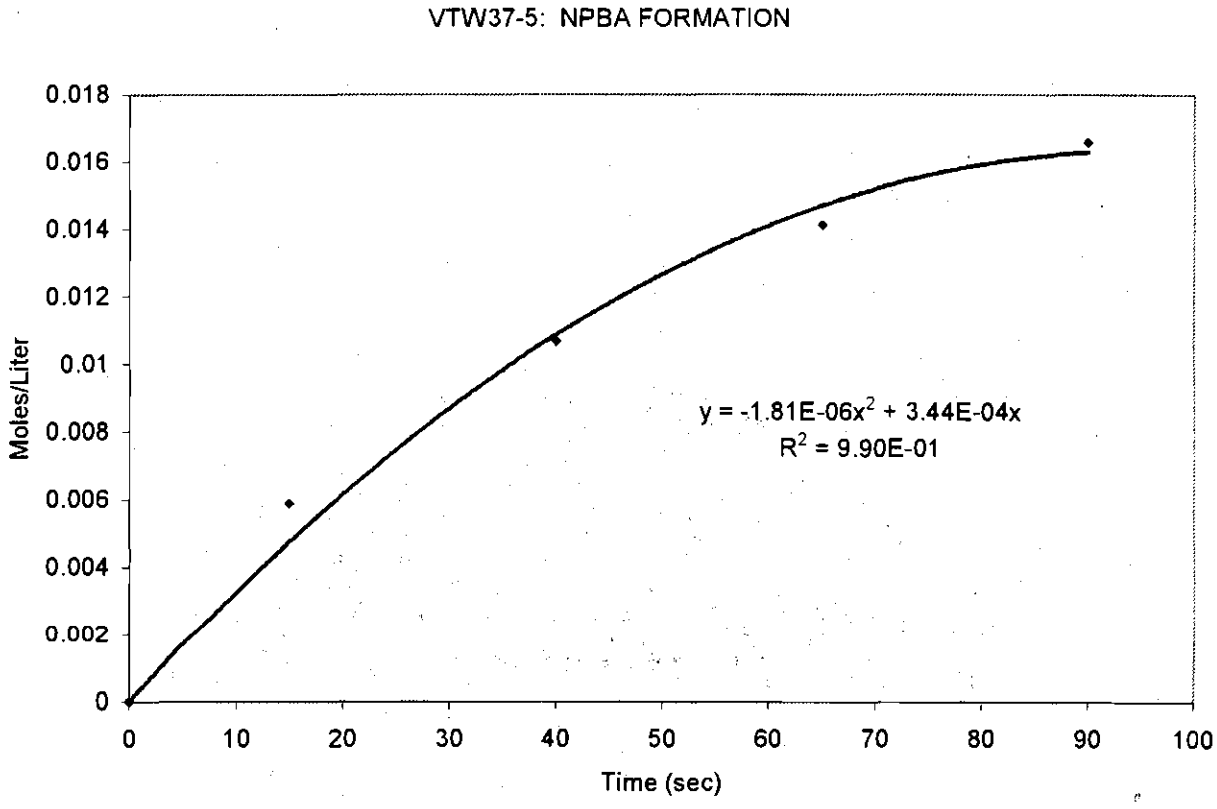


Figure 3.6. N-benzylation of Acetanilide (100ml / 0.50 ml: 1,2-dichlorobenzene/ Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**0.50 ml Water**	0.0 moles KCl

Table 3.6. N-benzylation of Acetanilide (100ml / 0.50 ml: 1,2-dichlorobenzene/ Water) at 78°C.

TIME (sec)	NPBA
0.0	0.0
15	0.0059
40	0.0107
65	0.0141
90	0.0166
120	0.0192
150	0.0219
180	0.0245
240	0.0287
300	0.0320
420	0.0368
600	0.0412
900	0.0442
1200	0.0450
1500	0.0456
2100	0.0461

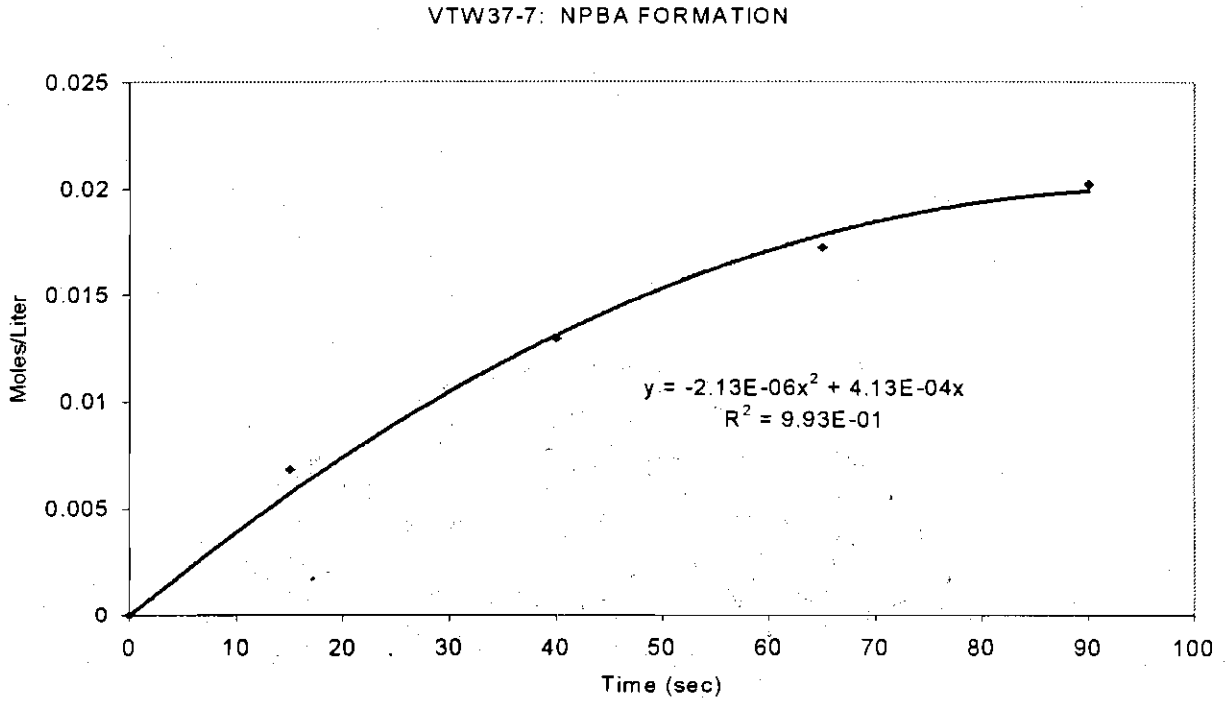


Figure 3.7. N-benzylation of Acetanilide (100ml / 0.50 ml: 1,2-dichlorobenzene/ Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**0.50 ml Water**	0.0 moles KCl

Figure 3.7. N-benzylation of Acetanilide (100ml / 0.50 ml: 1,2-dichlorobenzene/ Water) at 78°C.

TIME (sec)	NPBA
0	0
15	0.0069
40	0.0129
65	0.0173
90	0.0202
120	0.0234
150	0.0263
180	0.0290
240	0.0328
300	0.0359
420	0.0399
600	0.0431
900	0.0460
1200	0.0466
1500	0.0469
2100	0.0476

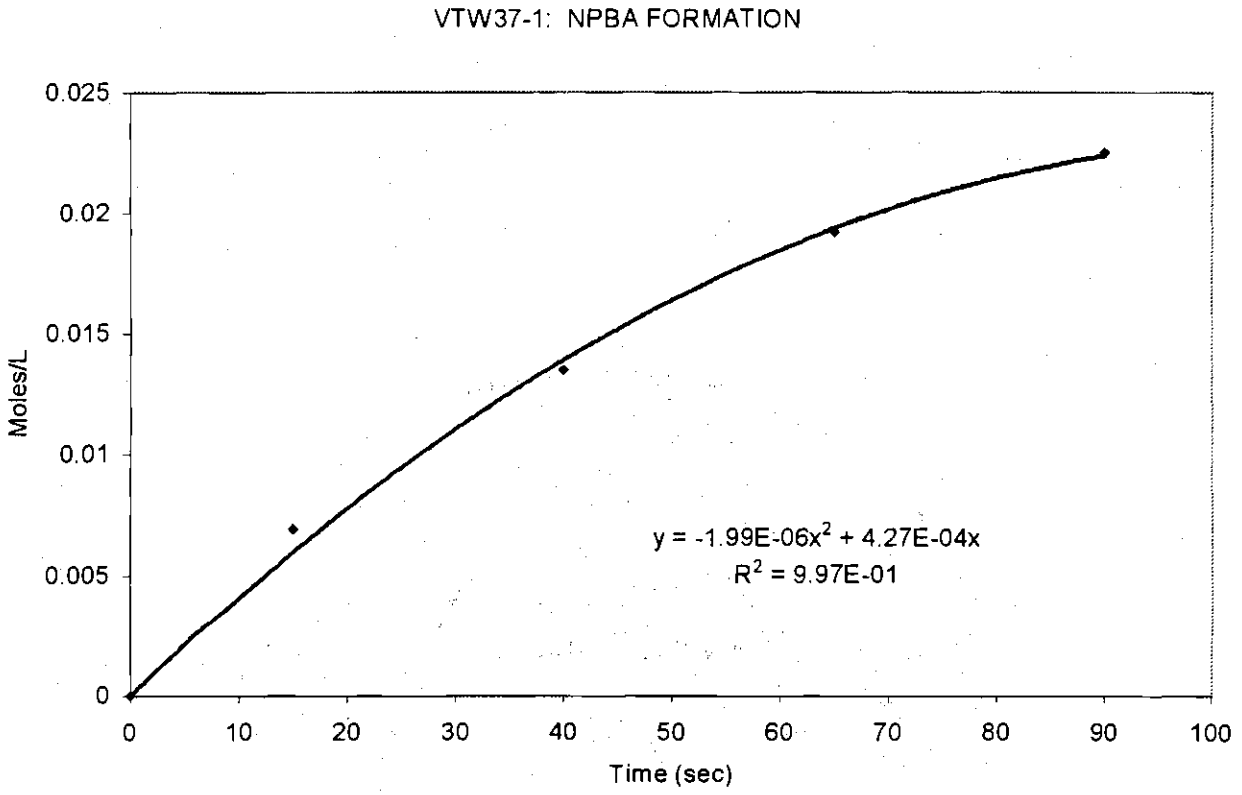


Figure 3.8. N-benzylation of Acetanilide (100ml / 1.0 ml: 1,2-dichlorobenzene/ Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**1.0 ml Water**	0.0 moles KCl

Figure 3.8. N-benzylation of Acetanilide (100ml / 1.0 ml: 1,2-dichlorobenzene/ Water) at 78°C.

TIME (sec)	NPBA
0	0.0
15	0.0069
40	0.0135
65	0.0192
90	0.0225
120	0.0251
150	0.0275
180	0.0295
240	0.0327
300	0.0350
450	0.0383
600	0.0405
900	0.0428
1200	0.0441
1500	0.0448
2100	0.0455
2700	0.0477
3600	0.0467

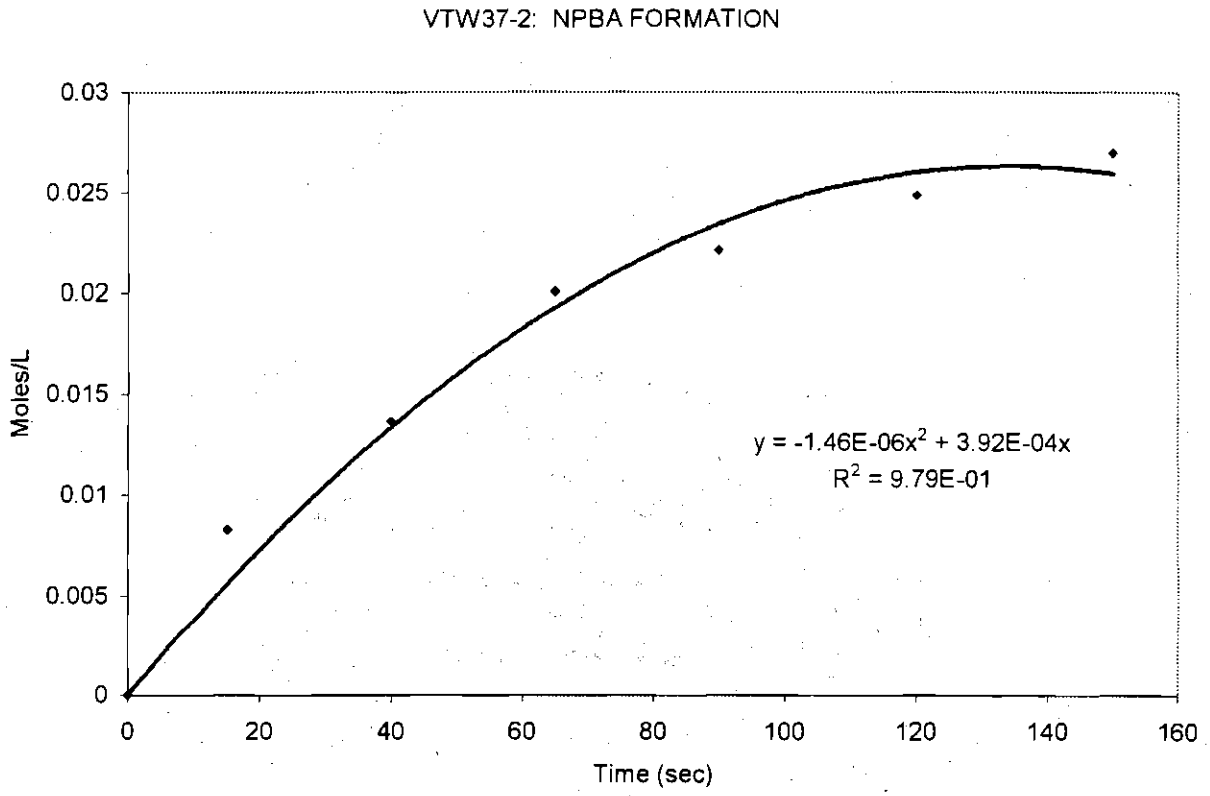


Figure 3.9. N-benzylation of Acetanilide (100ml / 1.0 ml: 1,2-dichlorobenzene/ Water) at 78°C.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate =840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	**1.0 ml Water**	0.0 moles KCl

Figure 3.9. N-benzylation of Acetanilide (100ml / 1.0 ml: 1,2-dichlorobenzene/ Water) at 78°C.

TIME (sec)	NPBA
0	0.0
15	0.0083
40	0.0137
65	0.0201
90	0.0221
120	0.0248
150	0.0270
180	0.0291
240	0.0321
300	0.0347
420	0.0374
600	0.0394
900	0.0414
1200	0.0430
1500	0.0448
2100	0.0448
2700	0.0450
3600	0.0453

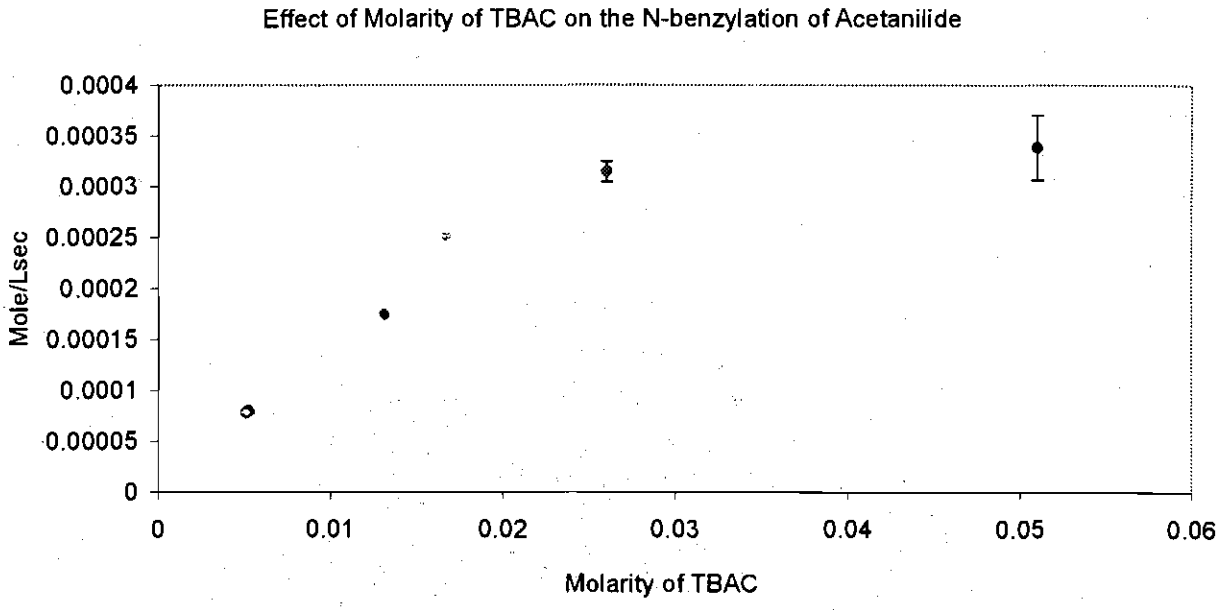


Figure 3.10. Effect of TBAC on the N-benzylation of Acetanilide

Table 3.10. Effect of TBAC on the N-benzylation of Acetanilide

Moles of TBAC	Initial Rate (Moles/Lsec)	Standard Deviation
0.0051	7.70×10^{-5}	N/A
0.013	1.74×10^{-4}	N/A
0.026	3.15×10^{-4}	1.0×10^{-5}
0.051	3.39×10^{-4}	3.2 x 10-5

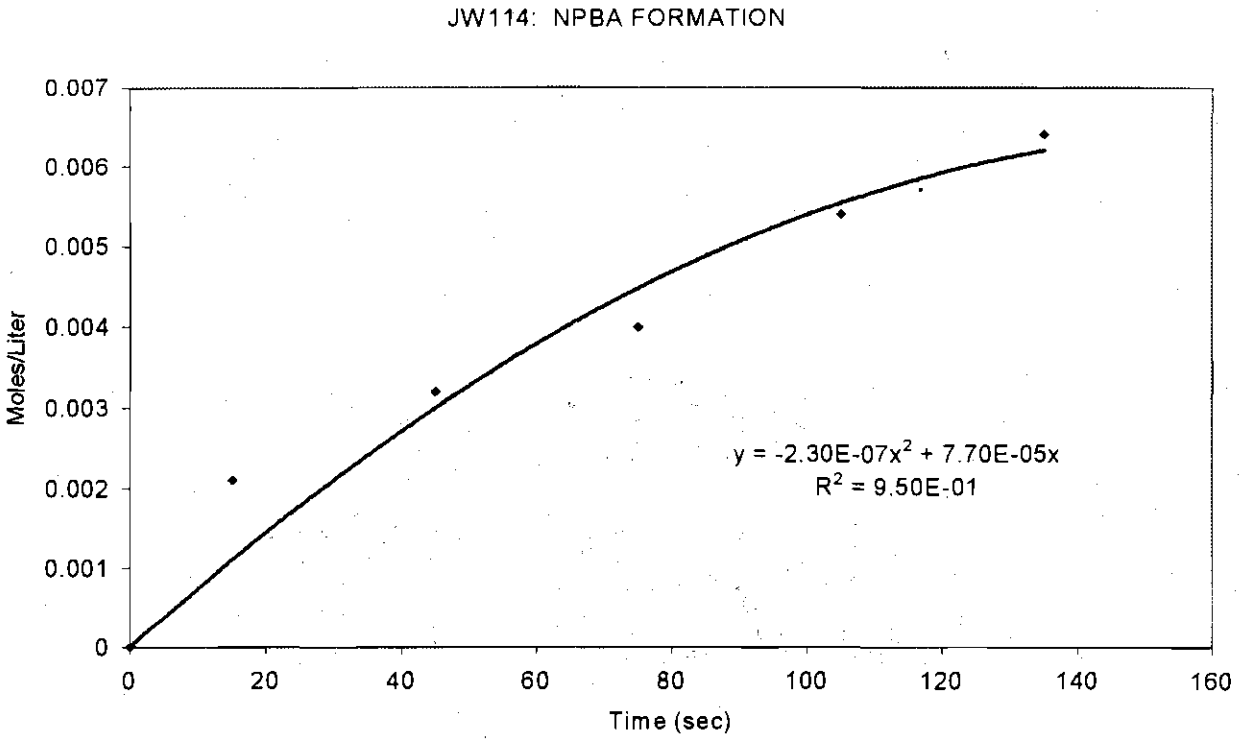


Figure 3.11. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.0051 M TBAC.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate= 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	**0.0051 M TBAC**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.11. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.0051 M TBAC.

TIME (sec)	NPBA
0	0
15	0.0021
45	0.0032
75	0.004
105	0.0054
135	0.0064
180	0.0083
241	0.00104
300	0.0125
420	0.0169
600	0.0218
900	0.0267
1200	0.0325
1500	0.0397
1800	0.0451
2400	0.0493
3000	0.0495
3600	0.0491
4800	0.0494

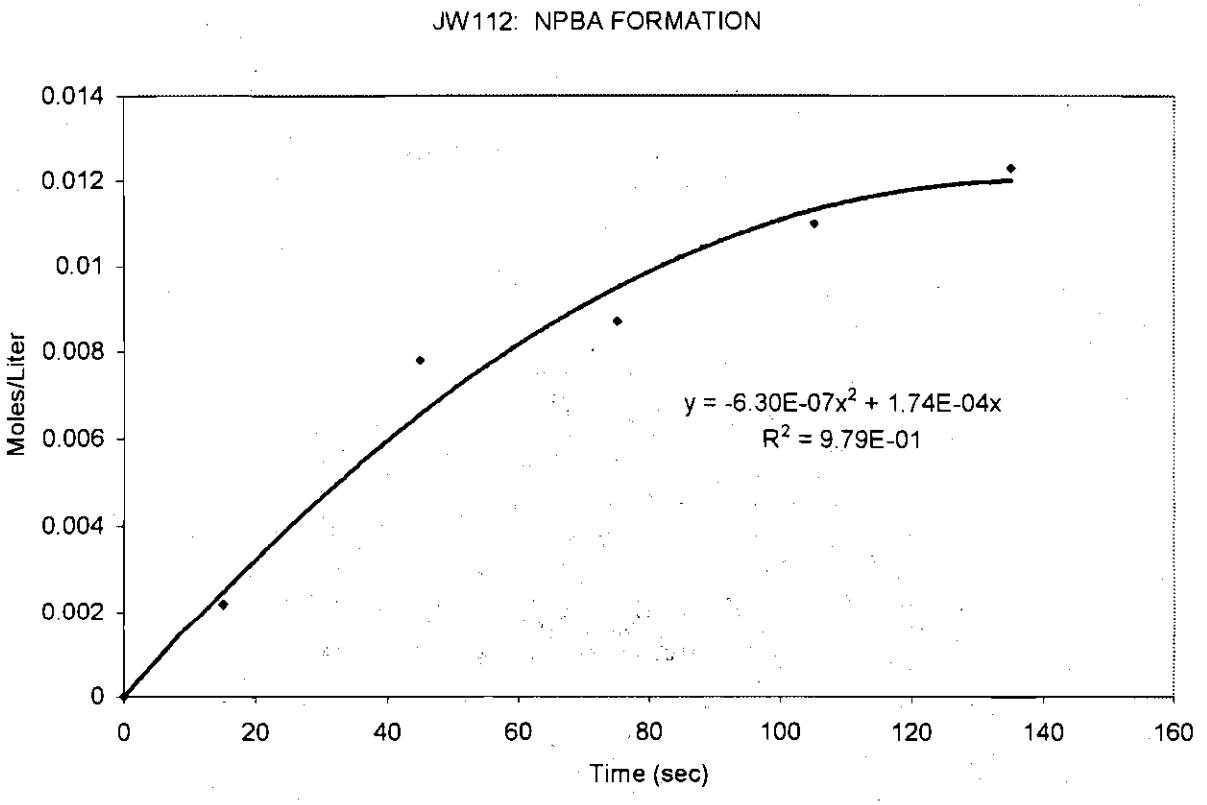


Figure 3.12. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.013 M TBAC.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate= 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	**0.013 M TBAC**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Figure 3.12. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.013 M TBAC.

TIME (sec)	NPBA
0	0
15	0.0022
45	0.0078
75	0.0087
105	0.011
135	0.0123
166.2	0.0143
195	0.0146
225	0.0162
255	0.0179
285	0.0182
315	0.0197
360	0.0195
421.2	0.0217
480	0.0238
540	0.0259
601.2	0.0281
780	0.0335
900	0.0349
1200	0.0442
1500	0.0485
1803	0.0485
2106	0.0500
2400	0.0478
2700	0.0453
3000	0.0486

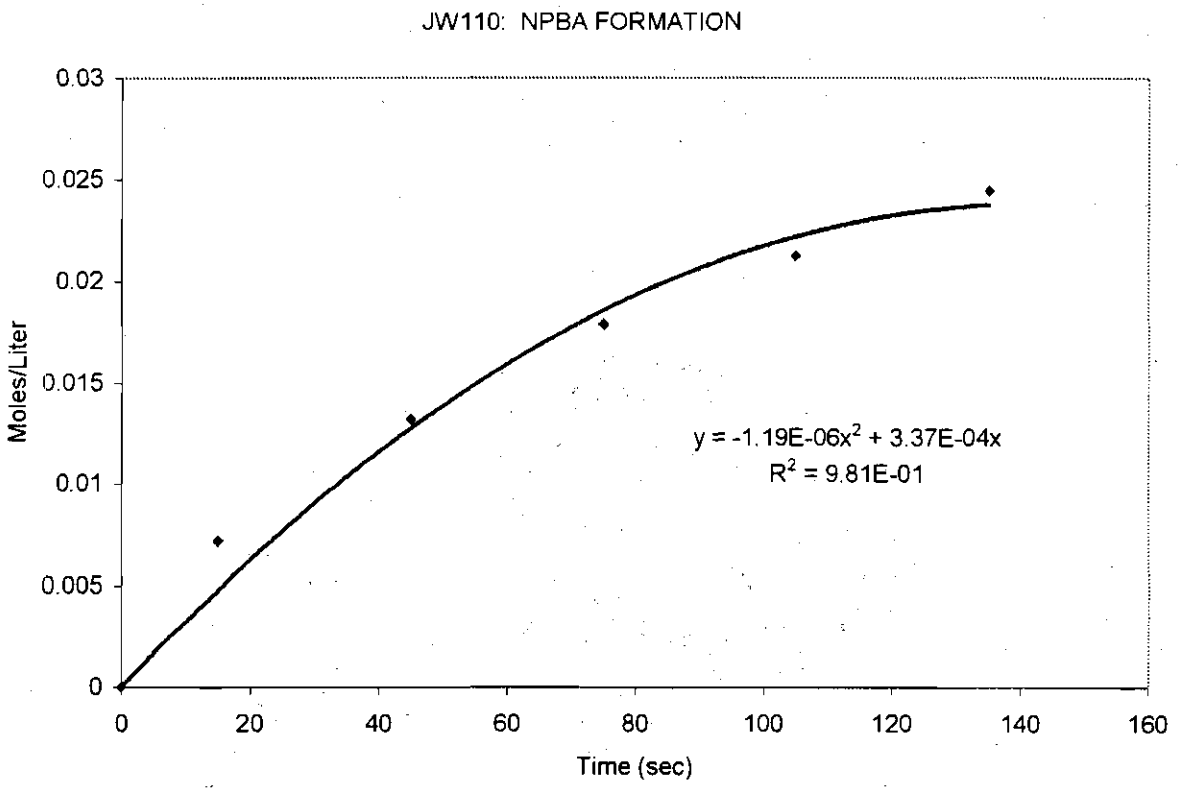


Figure 3.13. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.026 M TBAC.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate= 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	**0.026 M TBAC**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.13. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.026 M TBAC.

TIME (sec)	NPBA
0	0
15	0.0072
45	0.0132
75	0.0179
105	0.0213
135	0.0245
165	0.0258
195	0.0267
225	0.0272
315	0.0302
360	0.0324
421.2	0.0350
480	0.0375
540	0.0363
780	0.0391
1200	0.0433
1800	0.0436
2100	0.0434
2400	0.0407
2700	0.403

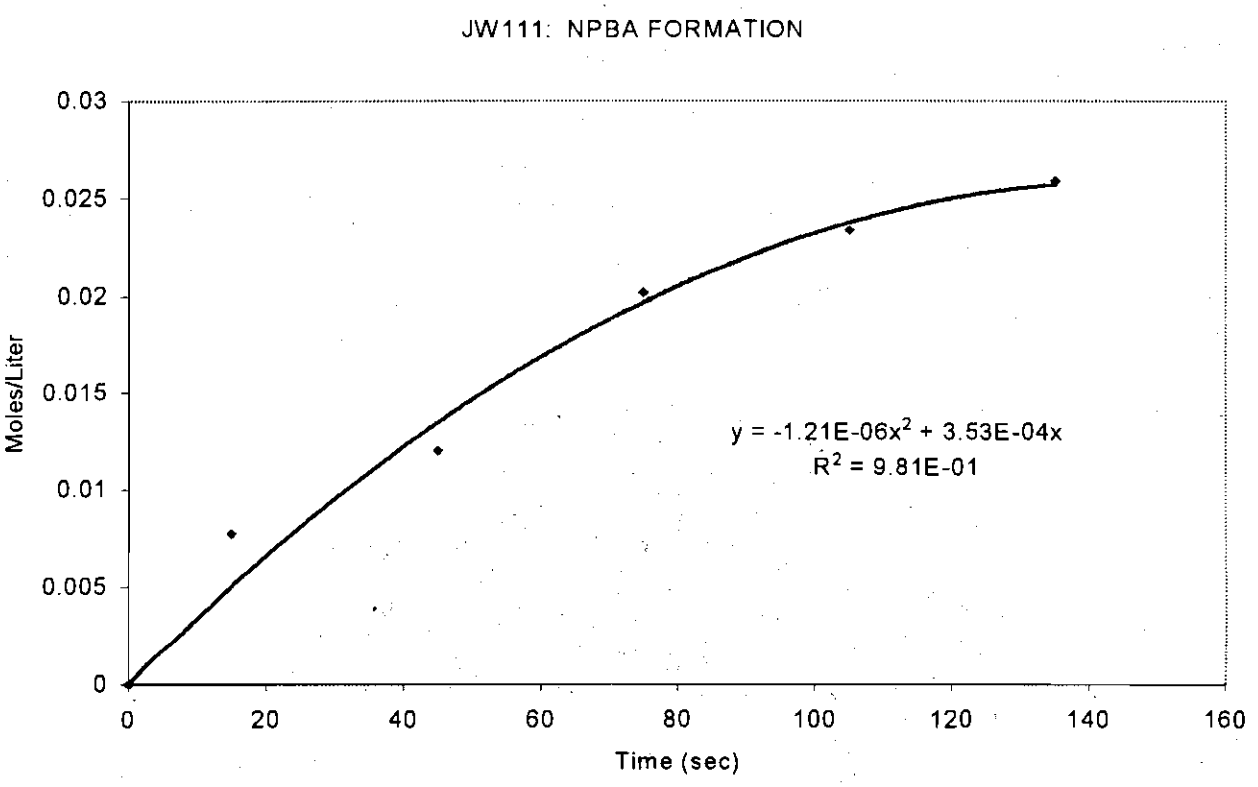


Figure 3.14. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.026 M TBAC.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate= 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	**0.026 M TBAC**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.14. Effect of TBAC on the N-benzylation of Acetanilide in the Presence of 0.026 M TBAC.

TIME (sec)	NPBA
0	0
15	0.0077
45	0.0120
75	0.0202
105	0.0234
135	0.0259
165	0.0264
195	0.0284
255	0.0317
285	0.0330
315	0.0338
360	0.0346
421.2	0.0356
480	0.0409
540	0.0412
601.2	0.0424
780	0.0439
900	0.0474
1200	0.0430
1500	0.0456
1800	0.0483
2100	0.0482
2400	0.0496
2700	0.0478
3000	0.0501

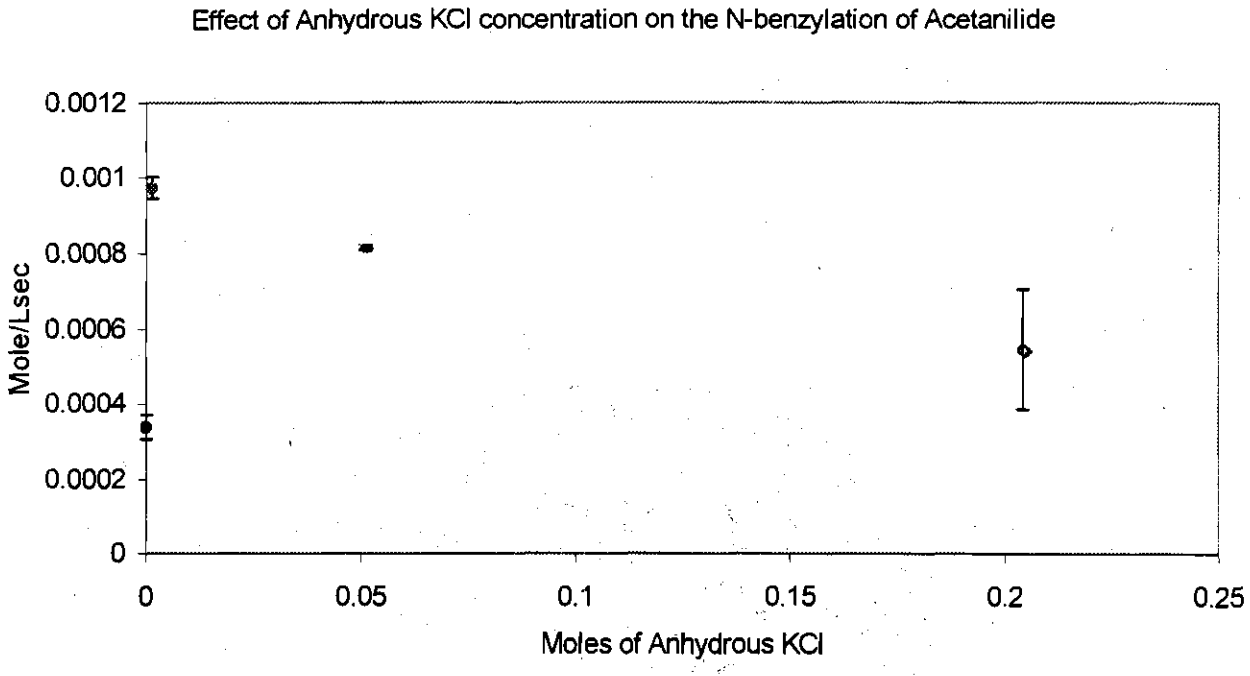


Figure 3.15. Effect of Anhydrous KCl on the N-benzylation of Acetanilide

MOLES OF ANHYDROUS KCl	INITIAL RATE (mole/Lsec)	STANDARD DEVIATION
0.0	3.39×10^{-4}	3.20×10^{-5}
0.00137	9.72×10^{-4}	2.85×10^{-5}
0.051	8.15×10^{-4}	6.70×10^{-5}
0.204	5.46×10^{-4}	1.60×10^{-4}

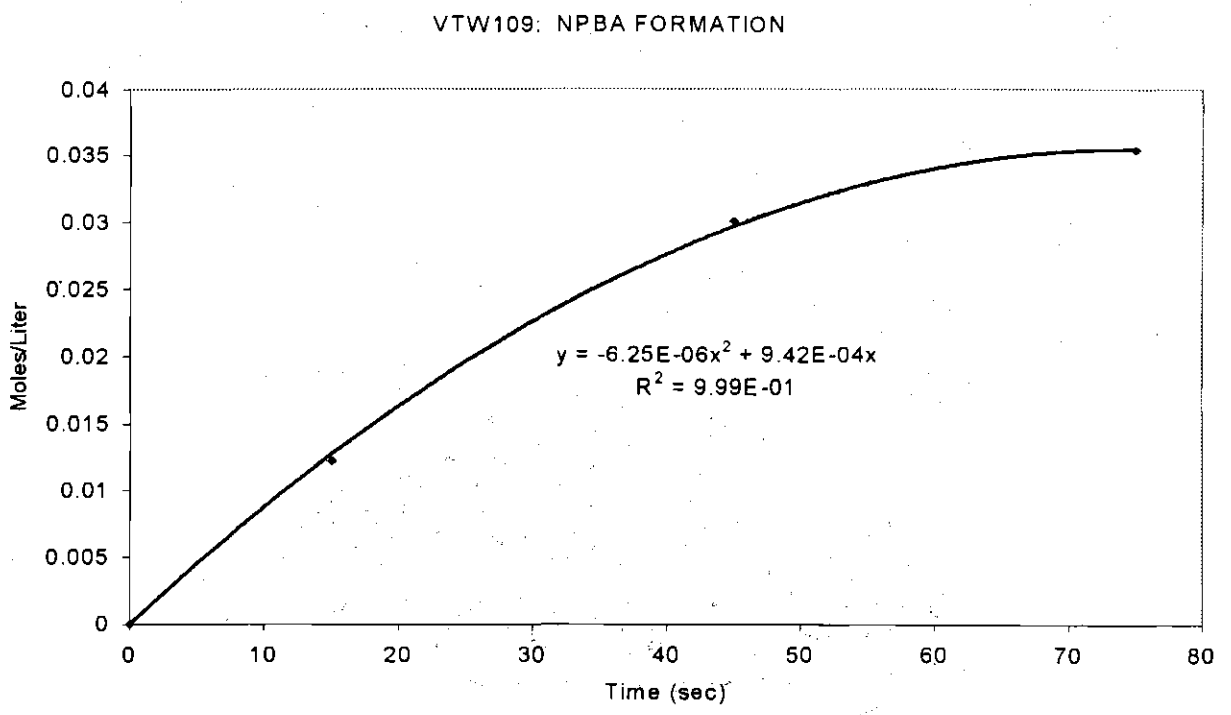


Figure 3.16. N-benzylation of Acetanilide in the Presence of 0.00137 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	**0.00137 moles KCl**

Table 3.16. N-benzylation of Acetanilide in the Presence of 0.00137 moles KCl.

TIME (sec)	NPBA
0	0
15	0.148
45	0.0268
75	0.0279
105	0.0283
135	0.0322
180	0.0331
240	0.0346
300	0.0363
360	0.0393
420	0.0396
480	0.0410
540	0.0403
600	0.0433
660	0.0397
720	0.0420
840	0.0419
900	0.0430
1200	0.0458
1500	0.0450
2160	0.0491
2700	0.0485
3600	0.0474

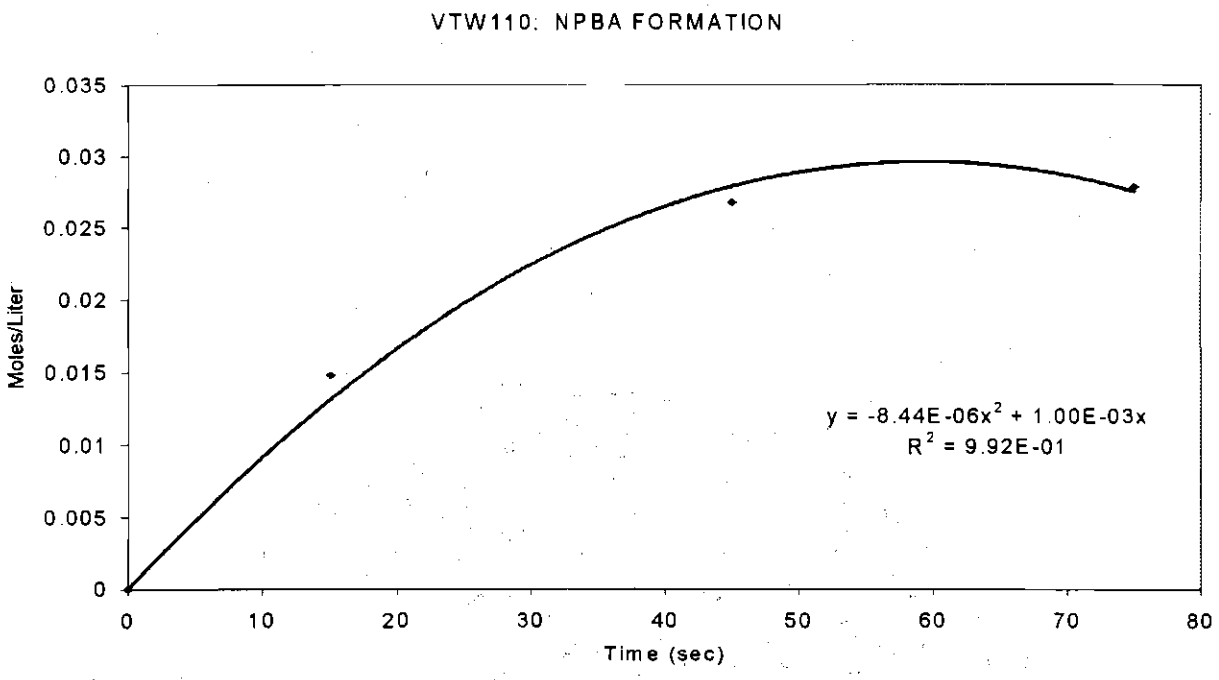


Figure 3.17. N-benzylation of Acetanilide in the Presence of 0.00137 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	**0.00137 moles KCl**

Table 3.17. N-benzylation of Acetanilide in the Presence of 0.00137 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0122
45	0.0301
75	0.0354
105	0.0375
129	0.0397
180	0.0401
240	0.0409
300	0.0451
360	0.0440
420	0.0464
480	0.0468
600	0.0471
660	0.0492
720	0.0468
840	0.0469
900	0.0477
1200	0.0485

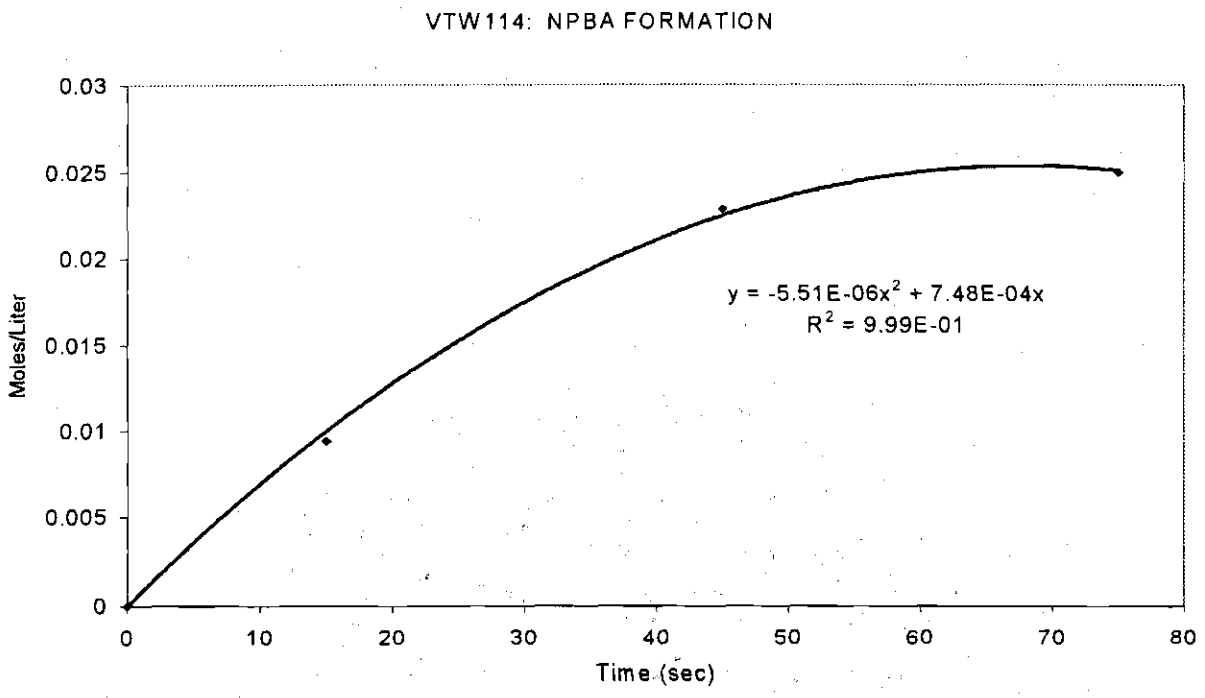


Figure 3.18. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	**0.051 moles KCl**

Table 3.17. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0094
45	0.0229
75	0.0250
105	0.0255
135	0.0261
180	0.0269
240	0.0293
660	0.0406
720	0.0425
780	0.0461
840	0.0440
900	0.0469
1200	0.059

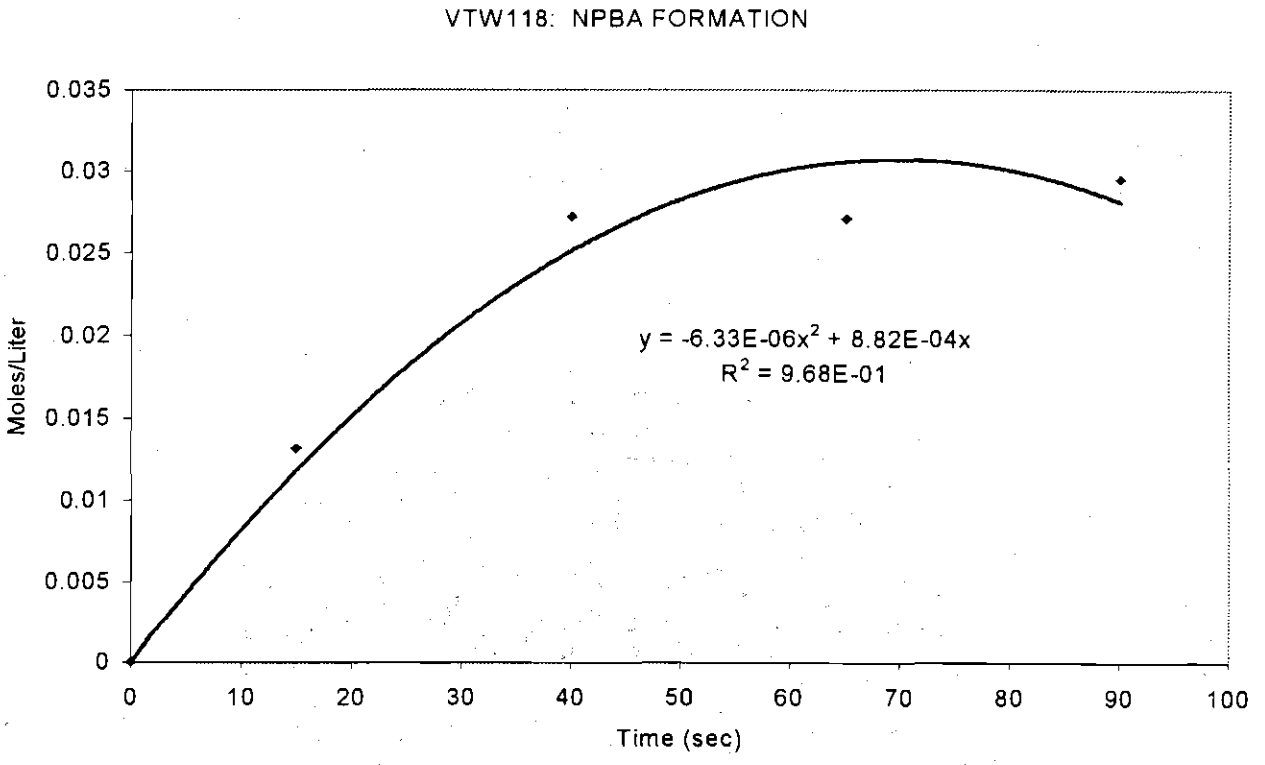


Figure 3.19. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	**0.051 moles KCl**

Table 3.19. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0132
40	0.0272
65	0.0271
90	0.0295
120	0.0281
150	0.0317
180	0.0338
240	0.0365
300	0.0334
360	0.0301
420	0.0355
480	0.0336
540	0.0352
600	0.0356
660	0.0383
720	0.0288
780	0.0282
840	0.0378
900	0.0349
1200	0.0374
1500	0.0318
2100	0.0354

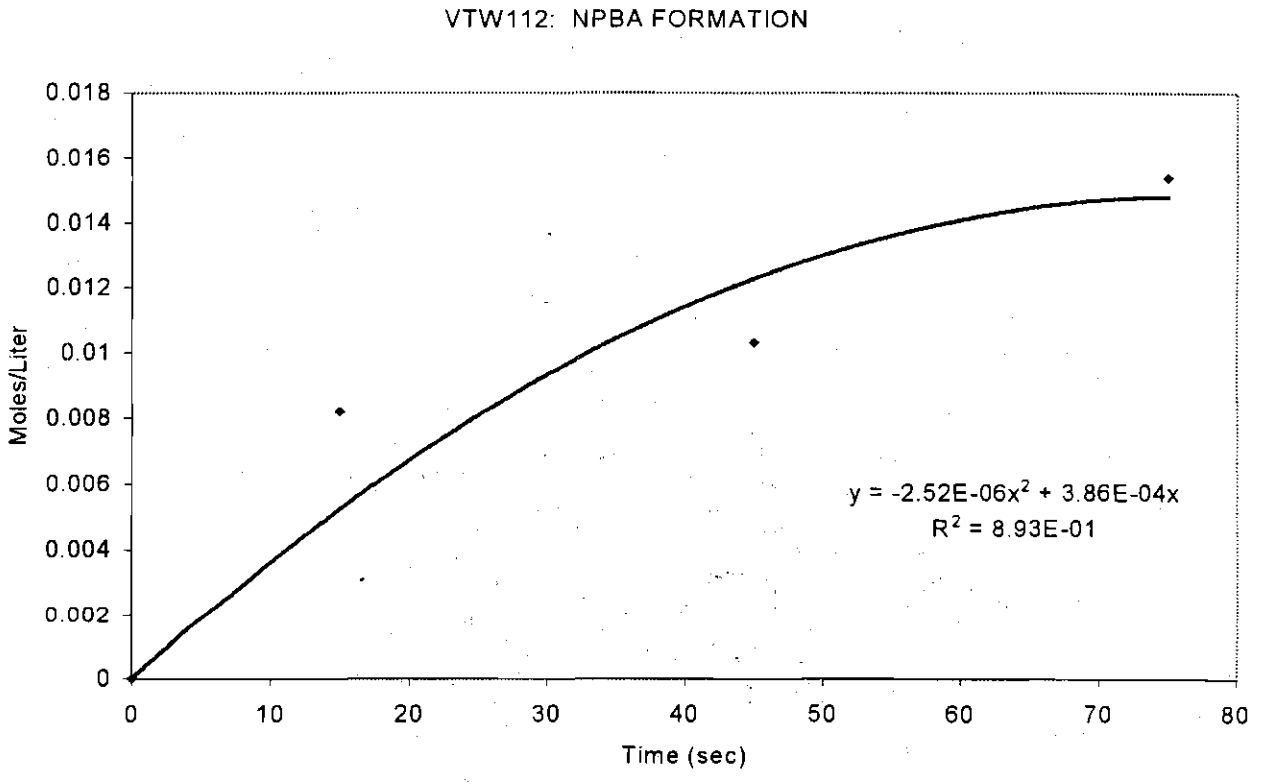


Figure 3.20. N-benzylation of Acetanilide in the Presence of 0.204 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	**0.204 moles KCl**

Table 3.20. N-benzylation of Acetanilide in the Presence of 0.204 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0082
45	0.0103
75	0.0154
105	0.0161
135	0.0185
180	0.0228
240	0.0237
300	0.0276
360	0.0321
420	0.0336
480	0.0374
540	0.0383
600	0.0422
660	0.0423
720	0.0422
780	0.0448
840	0.0457
900	0.0503

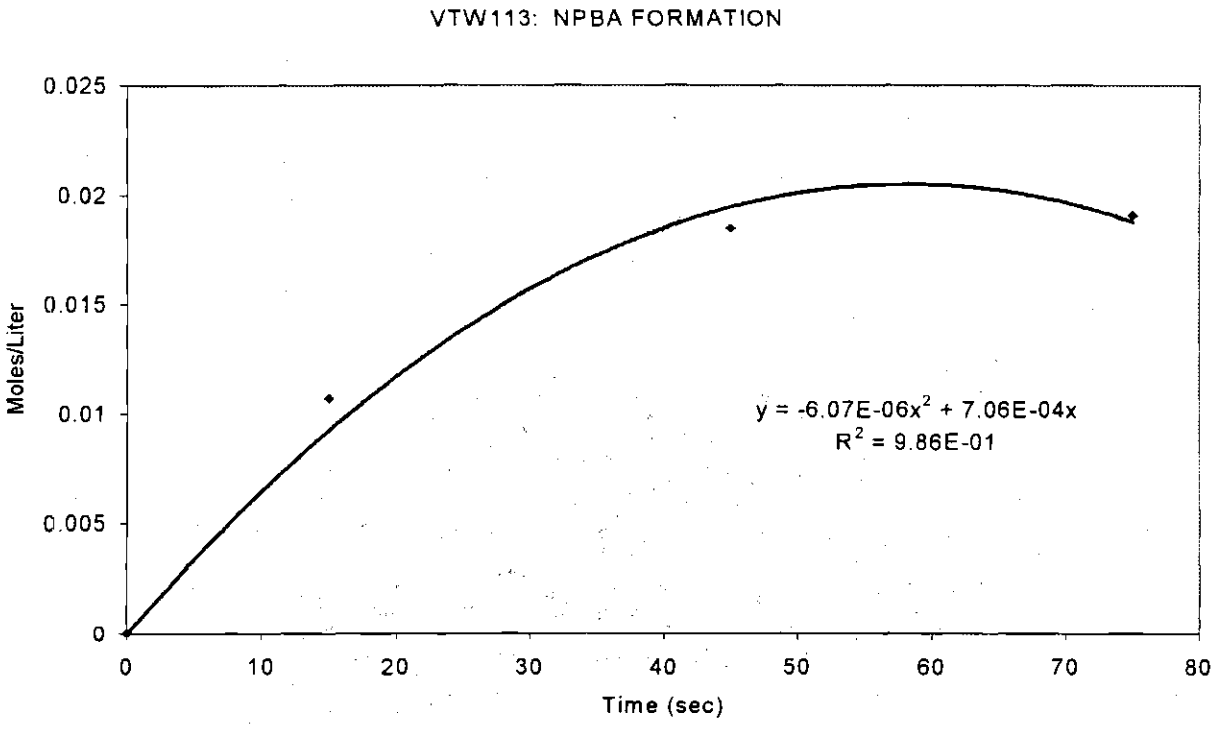


Figure 3.21. N-benzylation of Acetanilide in the Presence of 0.204 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	**0.204 moles KCl**

Table 3.21. N-benzylation of Acetanilide in the Presence of 0.204 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0107
45	0.0185
75	0.0191
105	0.0213
135	0.0221
180	0.0234
240	0.0260
300	0.0288
360	0.0313
420	0.0344
480	0.0350
540	0.0390
660	0.0404
720	0.0409
780	0.0422
840	0.0416
900	0.0456
1200	0.0477
1500	0.0470
2700	0.0494

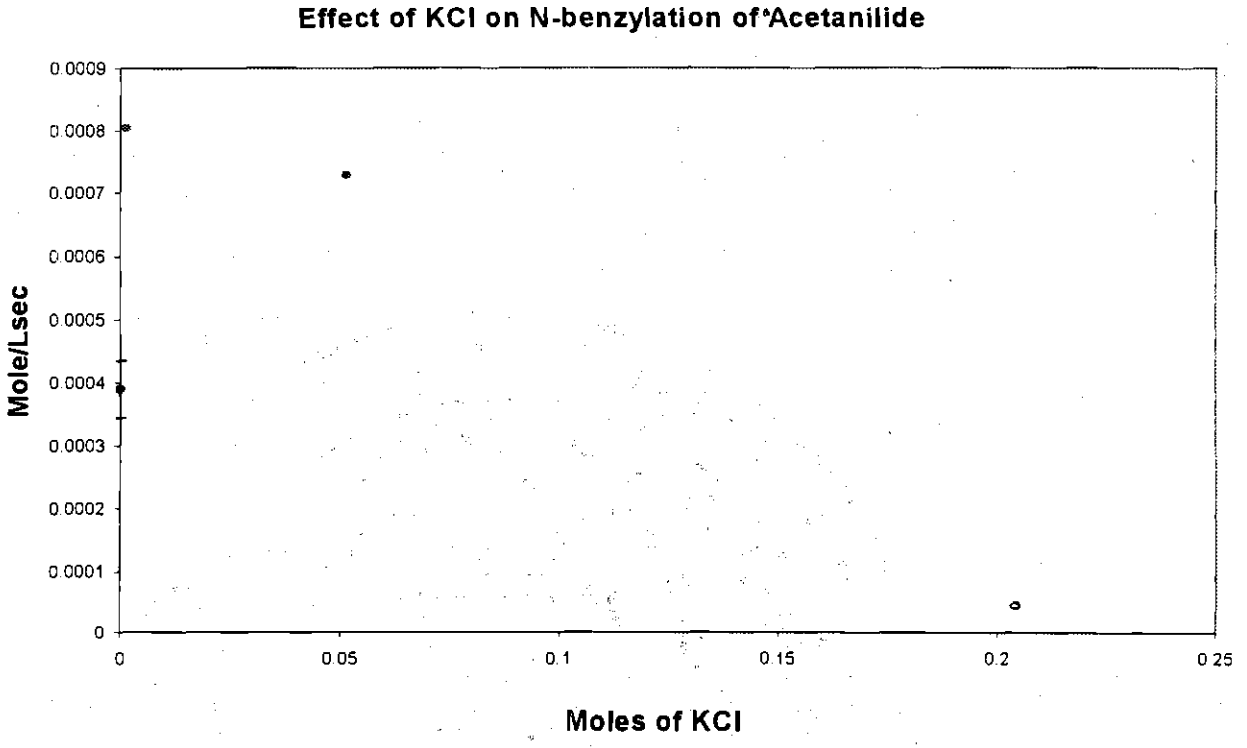


Figure 3.22. Effect of KCl on N-benzylation of Acetanilide.

Table 3.22. Effect of KCl on N-benzylation of Acetanilide

MOLES OF KCl	INITIAL RATE (Moles/Lsec)
0 moles	3.39×10^{-4}
0.00137 moles	8.04×10^{-4}
0.051 moles	7.30×10^{-4}
0.204 moles	4.70×10^{-5}

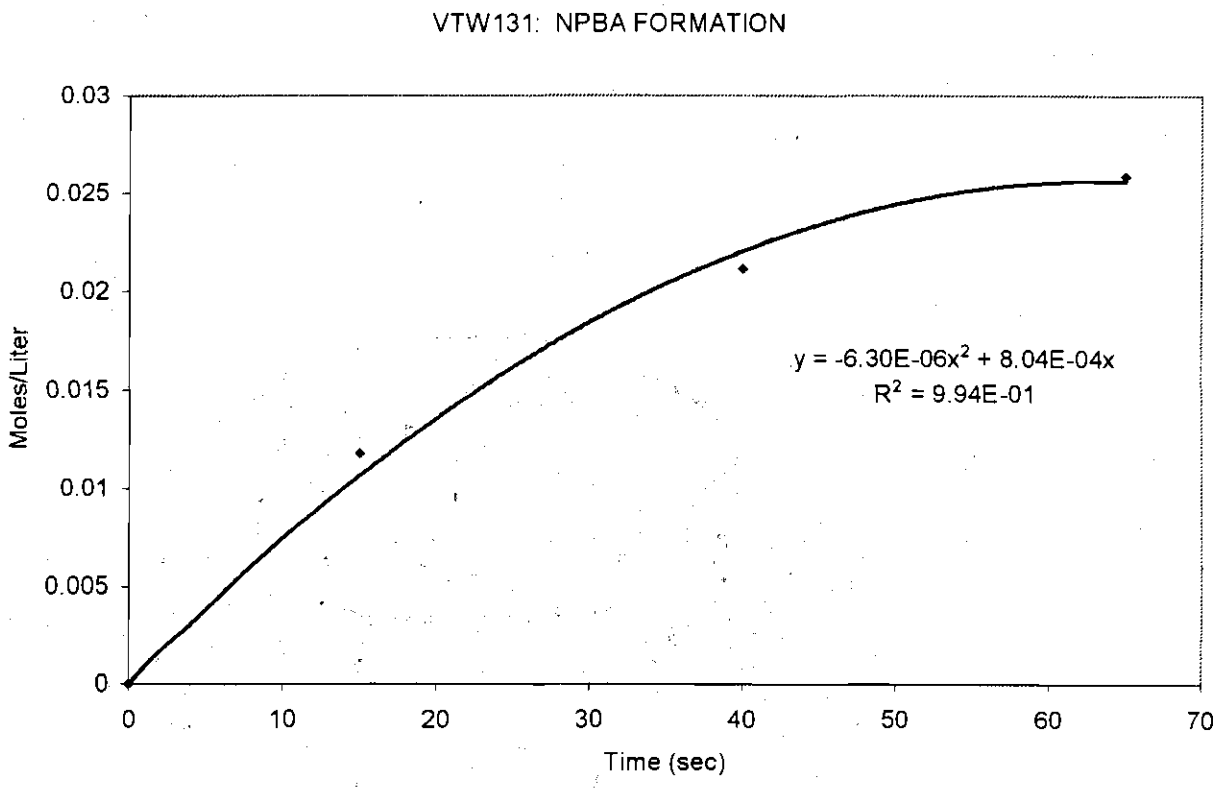


Figure 3.23. N-benzylation of Acetanilide in the Presence of 0.00137 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.054 M TBAC
0.054 moles KOH	0.0 ml Water	**0.00137 moles KCl**

Table 3.23. N-benzylation of Acetanilide in the Presence of 0.00137 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0118
40	0.0212
65	0.0259
90	0.0296
120	0.0301
150	0.0318
180	0.0323
240	0.0369
300	0.0384
420	0.0423
600	0.0449
900	0.0473
1500	0.0485
2700	0.0480
3600	0.0464

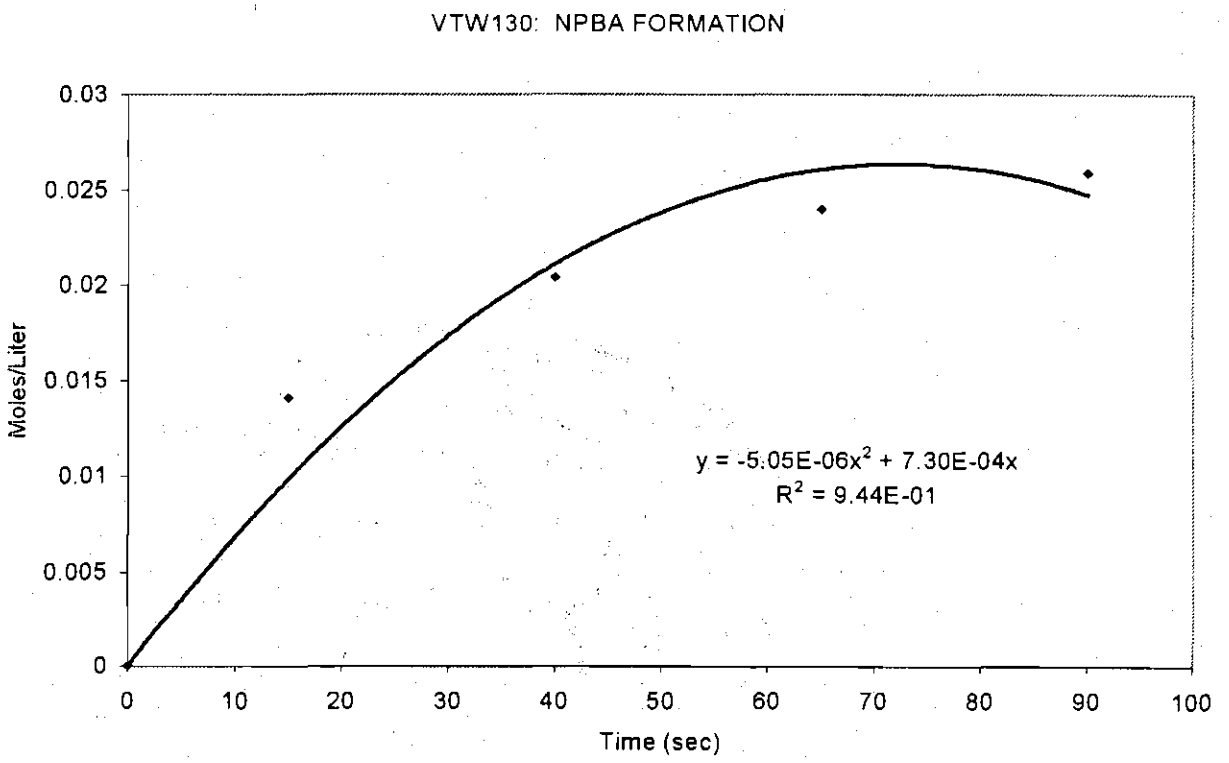


Figure 3.24. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.054 M TBAC
0.054 moles KOH	0.0 ml Water	**0.051 moles KCl**

Figure 3.24. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

TIME (sec)	NPBA
0	0
15	0.0141
40	0.0204
65	0.0240
90	0.0259
120	0.0303
240	0.0352
300	0.0367
420	0.0405
600	0.0405
900	0.0466
1200	0.0498
1500	0.0501

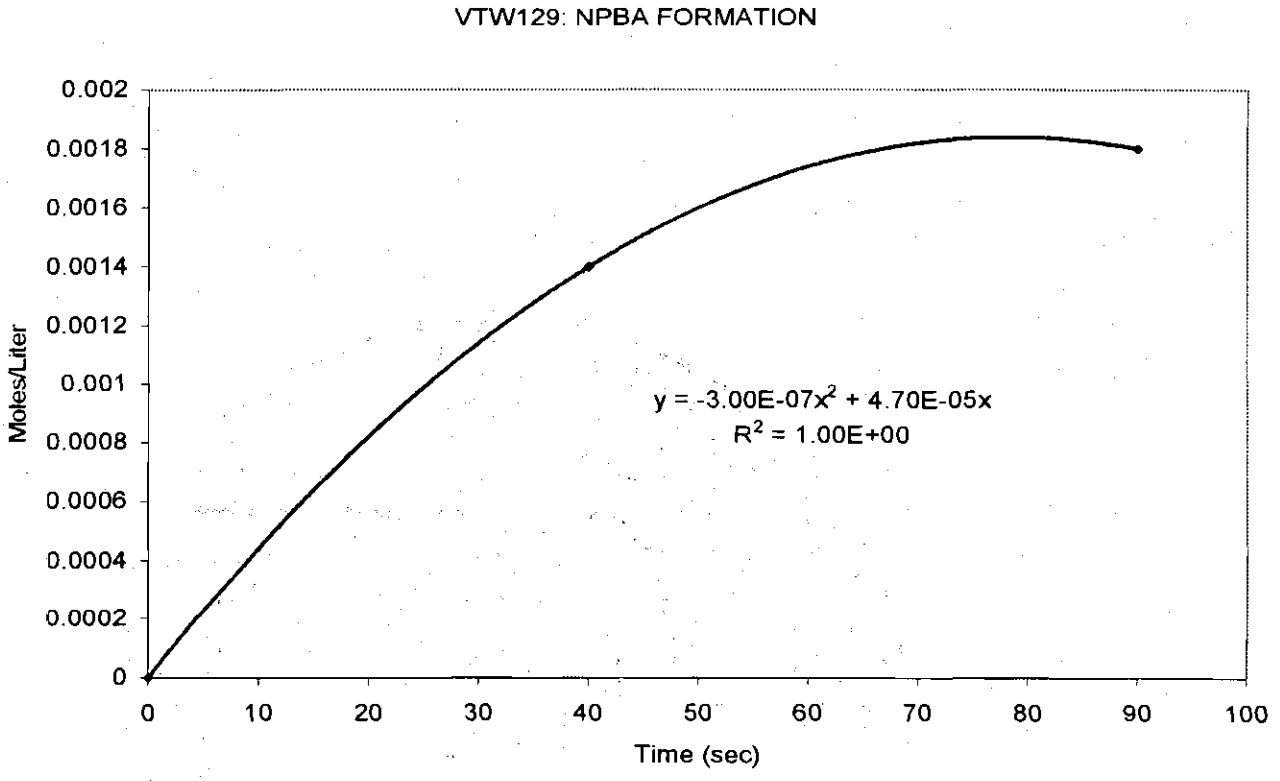


Figure 3.25. N-benzylation of Acetanilide in the Presence of 0.204 moles KCl.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 M Benzyl Chloride	0.054 M TBAC
0.054 moles KOH	0.0 ml Water	**0.204 moles KCl**

Figure 3.25. N-benzylation of Acetanilide in the Presence of 0.051 moles KCl.

TIME (sec)	NPBA
0	0
40	0.0014
90	0.0018
180	0.0022
240	0.0021
300	0.0026
420	0.0032
600	0.0036
900	0.0048
1500	0.0053

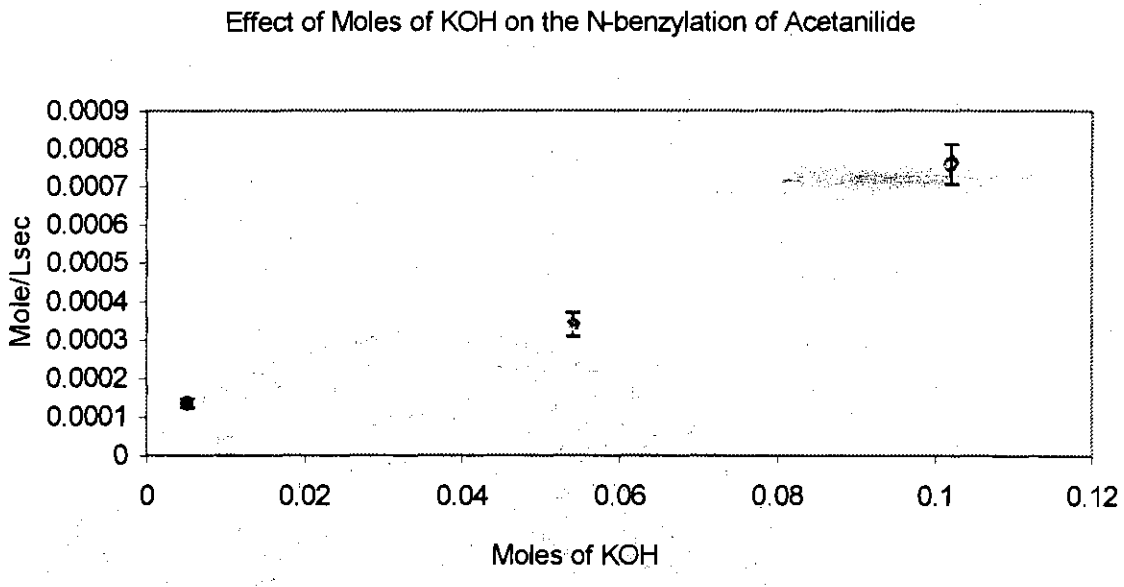


Figure 3.26. Effect of KOH on the N-benzylation of Acetanilide.

Table 3.26. Effect of KOH on the N-benzylation of Acetanilide.

MOLES OF KOH	INITIAL RATE (moles/Lsec)	STANDARD DEVIATION
0.0051	1.35×10^{-4}	1.15×10^{-5}
0.054	3.39×10^{-4}	3.20×10^{-5}
0.102	7.60×10^{-4}	5.25×10^{-5}

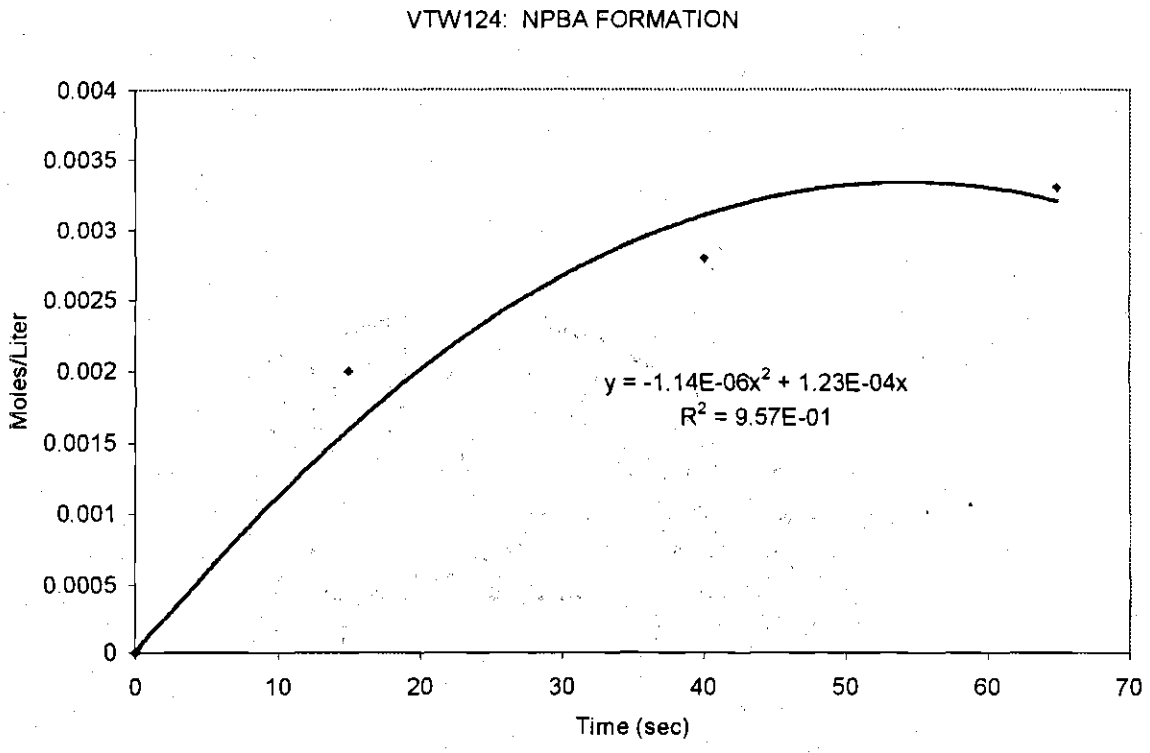


Figure 3.27. N-benzylation of Acetanilide in the Presence of 0.0051 moles KOH.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 Benzyl Chloride	0.051 M TBAC
0.0051 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.27. N-benzylation of Acetanilide in the Presence of 0.0051 moles KOH.

TIME (sec)	NPBA
0	0
15	0.0020
40	0.0028
65	0.0033
180	0.0038
600	0.0041
900	0.0043
1200	0.0042
1500	0.0040
2100	0.0044
2700	0.0042
3600	0.0042

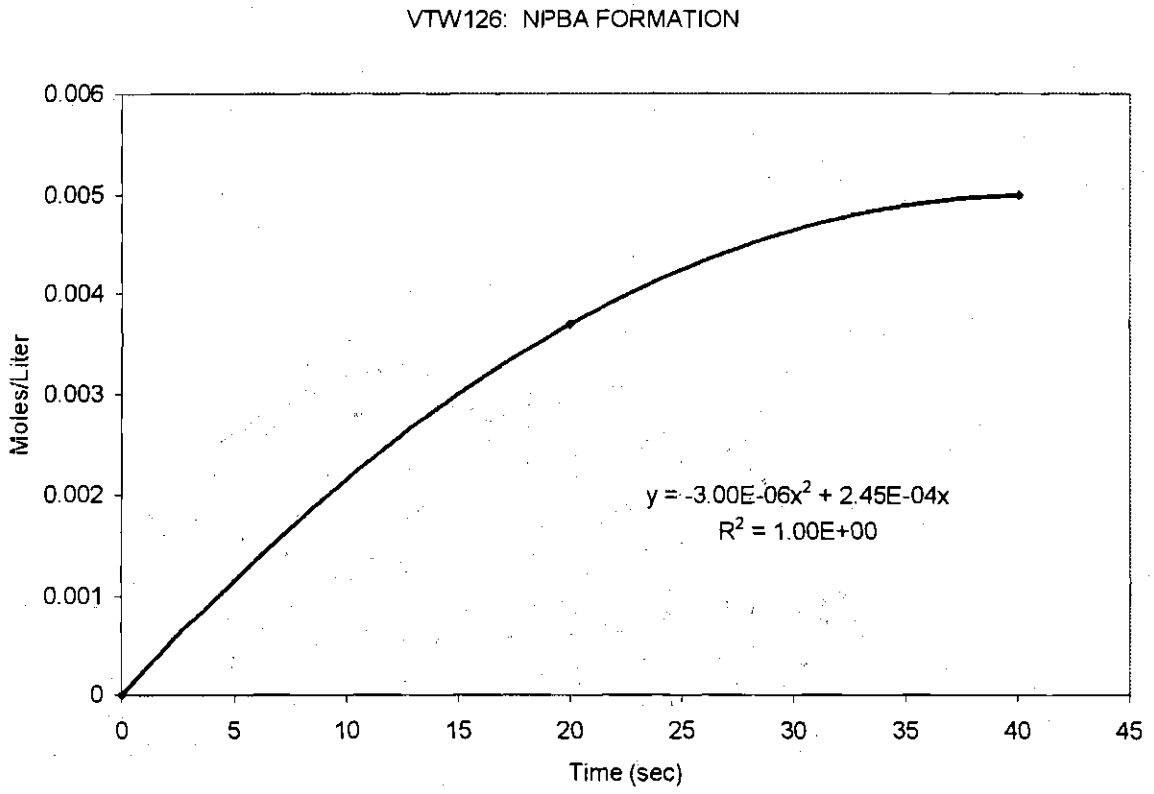


Figure 3.28. N-benzylation of Acetanilide in the Presence of 0.0051 moles KOH.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 Benzyl Chloride	0.051 M TBAC
0.0051 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.28. N-benzylation of Acetanilide in the Presence of 0.0051 moles KOH.

TIME (sec)	NPBA
0	0
15	0.0031
65	0.0036
90	0.0038
120	0.0038
150	0.0040
180	0.0042
420	0.0046
600	0.0043
900	0.0042
1200	0.0045
1500	0.0041
2700	0.0042
3600	0.0048

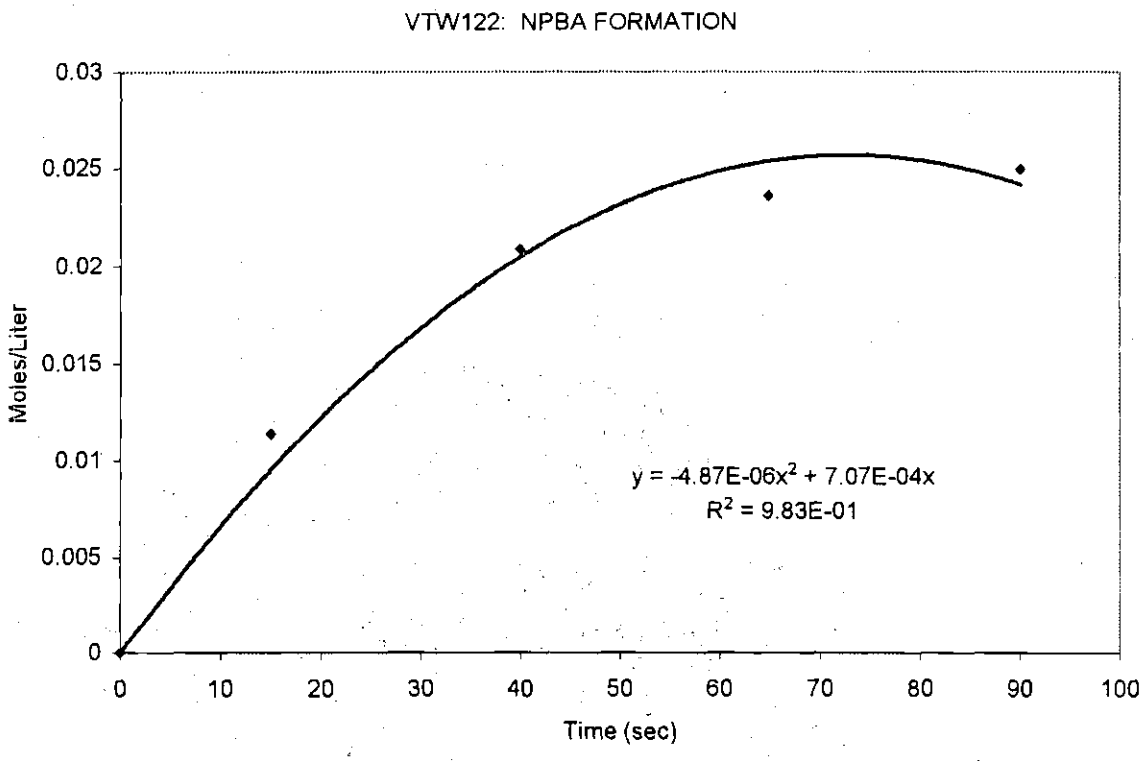


Figure 3.29. N-benzylation of Acetanilide in the Presence of 0.102 moles KOH.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 Benzyl Chloride	0.051 M TBAC
0.102 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.29. N-benzylation of Acetanilide in the Presence of 0.102 moles KOH.

TIME (sec)	NPBA
0	0
15	0.0037
40	0.0050
65	0.0061
90	0.0065
120	0.0079
150	0.0073
240	0.0084
600	0.0091
1500	0.0108
2100	0.0117
3600	0.0109

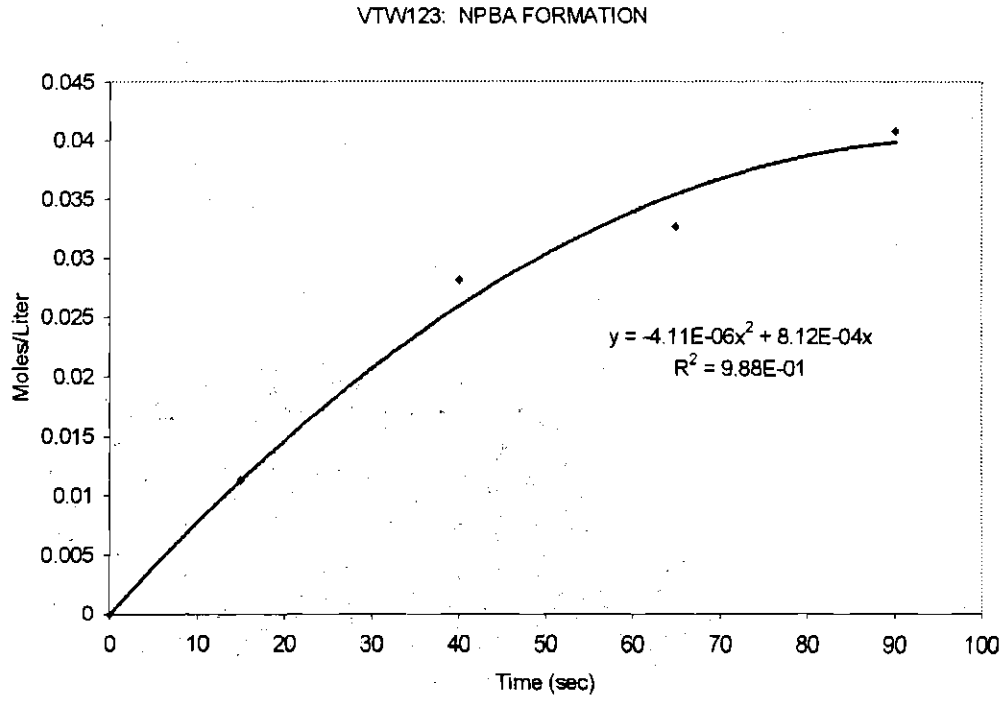


Figure 3.30. N-benzylation of Acetanilide in the Presence of 0.102 moles KOH.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	1.04 Benzyl Chloride	0.051 M TBAC
0.102 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.30. N-benzylation of Acetanilide in the Presence of 0.102 moles KOH.

TIME (sec)	NPBA
0	0
15	0.0113
40	0.0281
65	0.0327
90	0.0408
120	0.0367
150	0.0437
180	0.0491
240	0.0508
300	0.0498
420	0.0499
600	0.0472

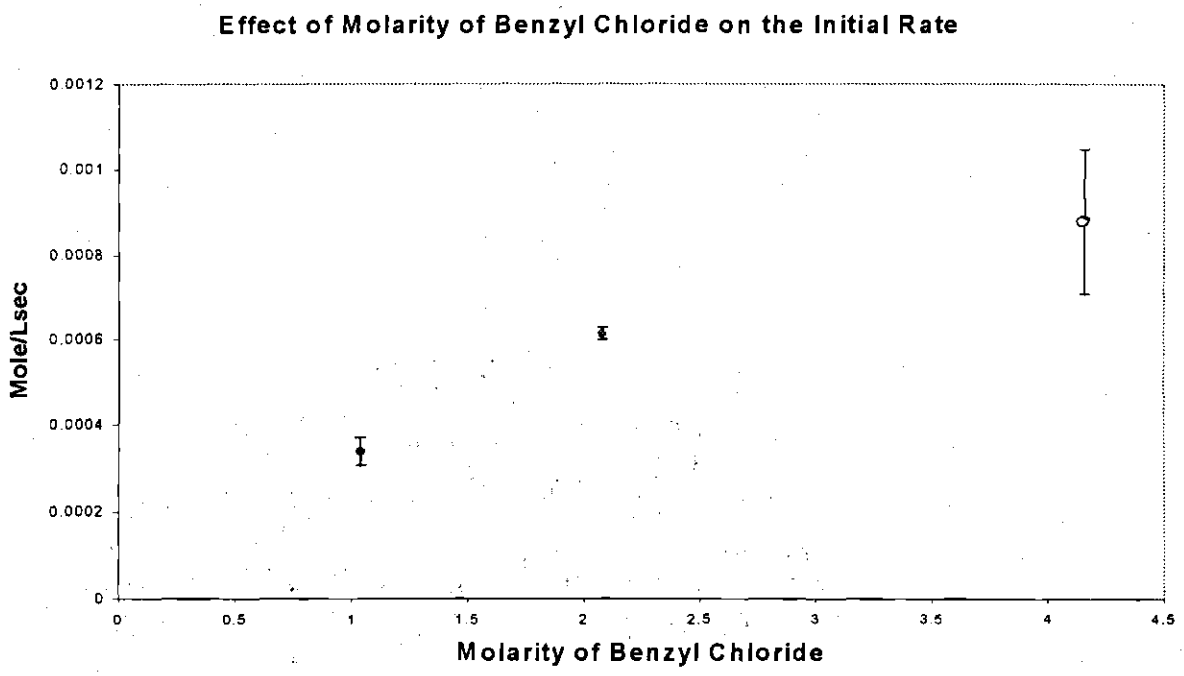


Figure 3.31. Effect of Benzyl Chloride on the N-benzylation of Acetanilide .

Table 3.31. Effect of Benzyl Chloride on the N-benzylation of Acetanilide .

MOLARITY OF BENZYL CHLORIDE	INITIAL RATE (Mole/Lsec)	STANDARD DEVIATION
1.04 M	3.39×10^{-4}	3.20×10^{-5}
2.08 M	6.14×10^{-4}	1.40×10^{-5}
4.16 M	8.79×10^{-4}	1.70×10^{-5}

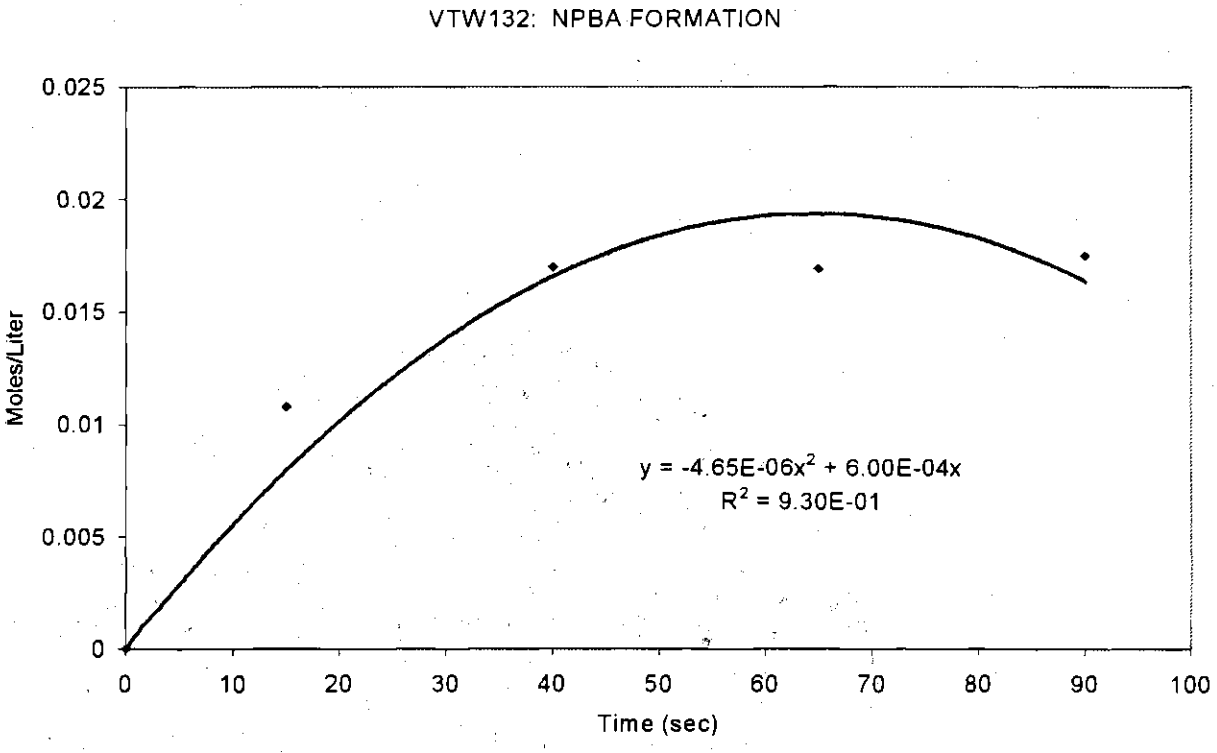


Figure 3.32. N-benzylation of Acetanilide in the Presence of 2.08 M Benzyl Chloride.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	**2.08 M Benzyl Chloride**	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.32. N-benzylation of Acetanilide in the Presence of 2.08 M Benzyl Chloride.

TIME (sec)	NPBA
0	0
15	0.0108
40	0.0170
64	0.0169
90	0.0175
120	0.0190
150	0.0210
180	0.0230
240	0.0260
300	0.0270
420	0.0354
900	0.0434
1200	0.0462
1500	0.0482
2100	0.0474
2700	0.0456

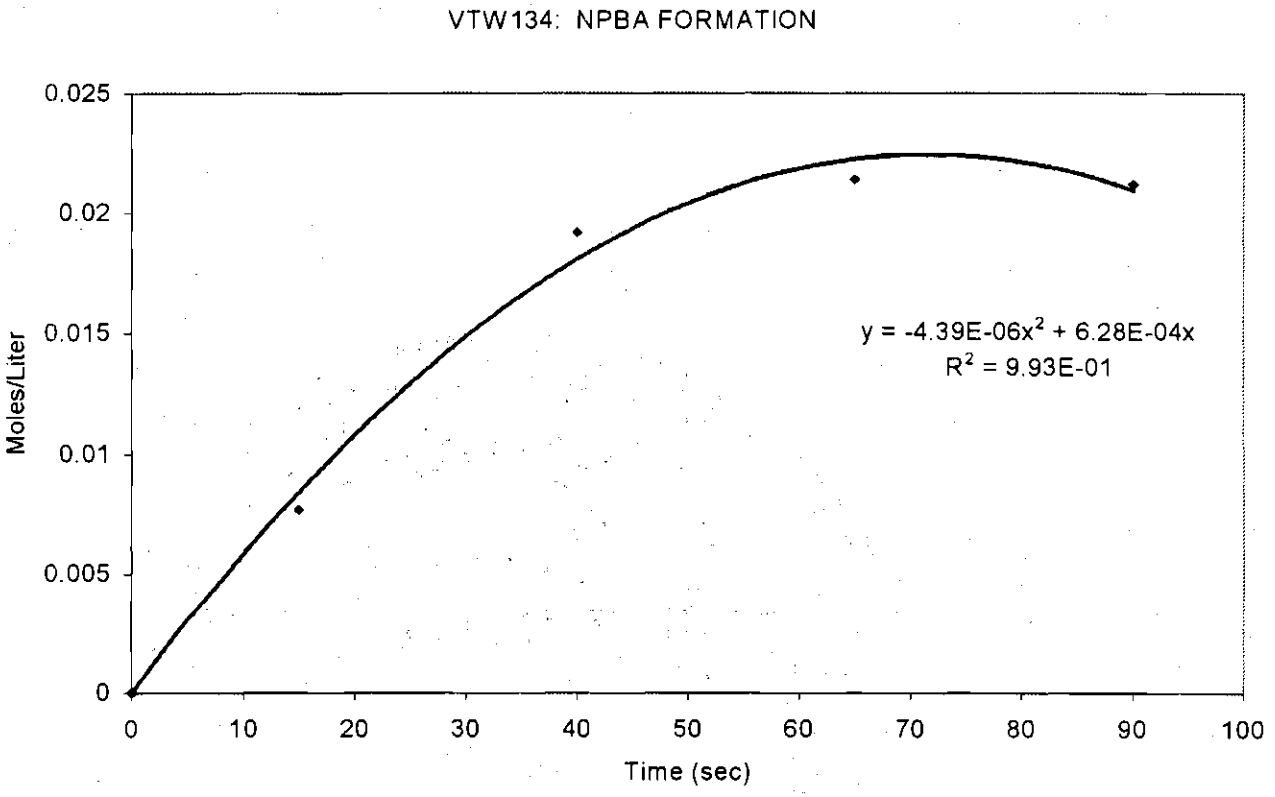


Figure 3.33. N-benzylation of Acetanilide in the Presence of 2.08 M Benzyl Chloride.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	**2.08 M Benzyl Chloride**	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.33. N-benzylation of Acetanilide in the Presence of 2.08 M Benzyl Chloride.

TIME (sec)	NPBA
0	0
15	0.0077
40	0.0192
64	0.0214
90	0.0212
120	0.0203
150	0.0237
300	0.0307
420	0.0361
600	0.0380
900	0.0426
1200	0.0436
1500	0.0438
2100	0.0410
2700	0.0395
3600	0.0445

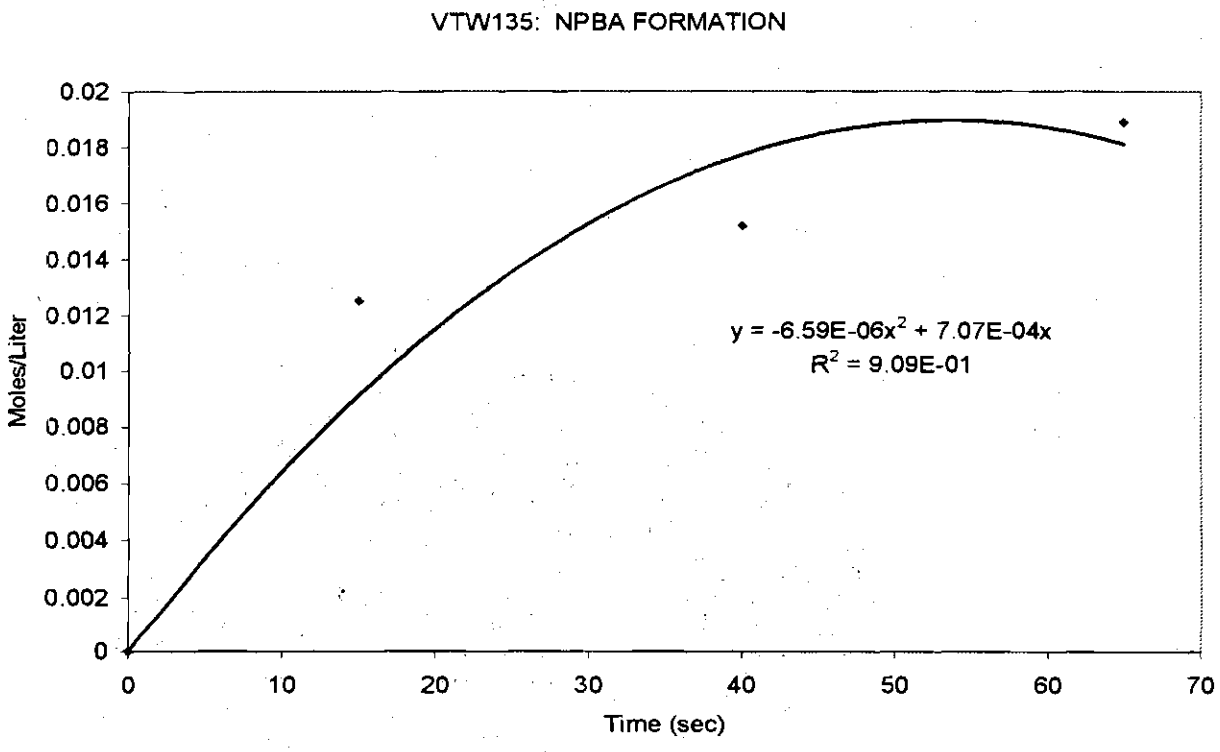


Figure 3.34. N-benzylation of Acetanilide in the Presence of 4.16 M Benzyl Chloride.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	**4.16 M Benzyl Chloride**	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.34. N-benzylation of Acetanilide in the Presence of 4.16 M Benzyl Chloride.

TIME (sec)	NPBA
0	0
15	0.0125
40	0.0152
65	0.0189
120	0.0212
150	0.0222
180	0.0220
240	0.0234
300	0.0284
420	0.0338
600	0.0426
900	0.0466
1200	0.0470
1500	0.0503
2100	0.0473
2700	0.0459

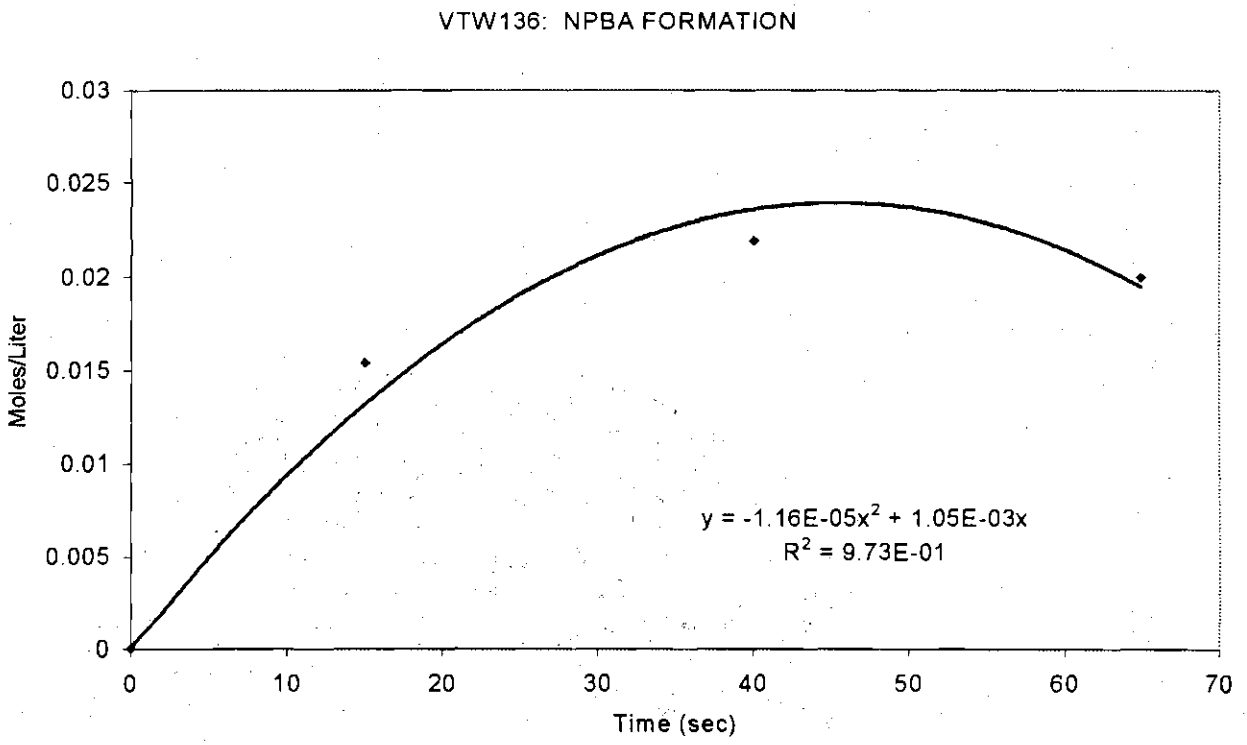


Figure 3.35. N-benzylation of Acetanilide in the Presence of 4.16 M Benzyl Chloride.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.51 M Acetanilide	**4.16 M Benzyl Chloride**	0.051 M TBAC
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.35. N-benzylation of Acetanilide in the Presence of 4.16 M Benzyl Chloride.

TIME (sec)	NPBA
0	0
15	0.0154
40	0.0219
65	0.0200
90	0.0216
150	0.0280
180	0.0269
240	0.0316
300	0.0348
420	0.0377
600	0.0435
900	0.0490
1500	0.0497
2100	0.0485
2700	0.0464

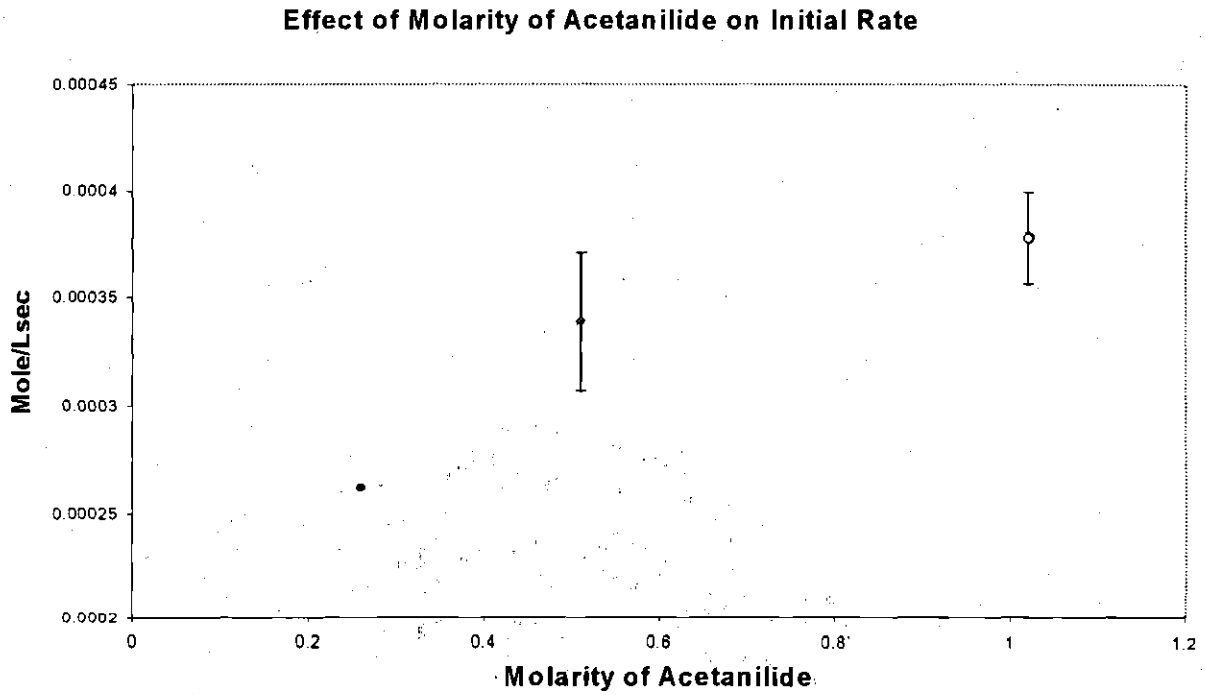


Figure 3.36. Effect of Molarity of Acetanilide on the Initial Rate of N-benzylation of Acetanilide.

Table 3.36. Effect of Molarity of Acetanilide on the Initial Rate of N-benzylation of Acetanilide.

MOLARITY OF ACETANILIDE (M)	INITIAL RATE (moles/Lsec)	STANDARD DEVIATION
0.26 M	2.62×10^{-4}	N/A
0.51 M	3.39×10^{-4}	3.20×10^{-5}
1.02 M	3.78×10^{-4}	2.15×10^{-5}

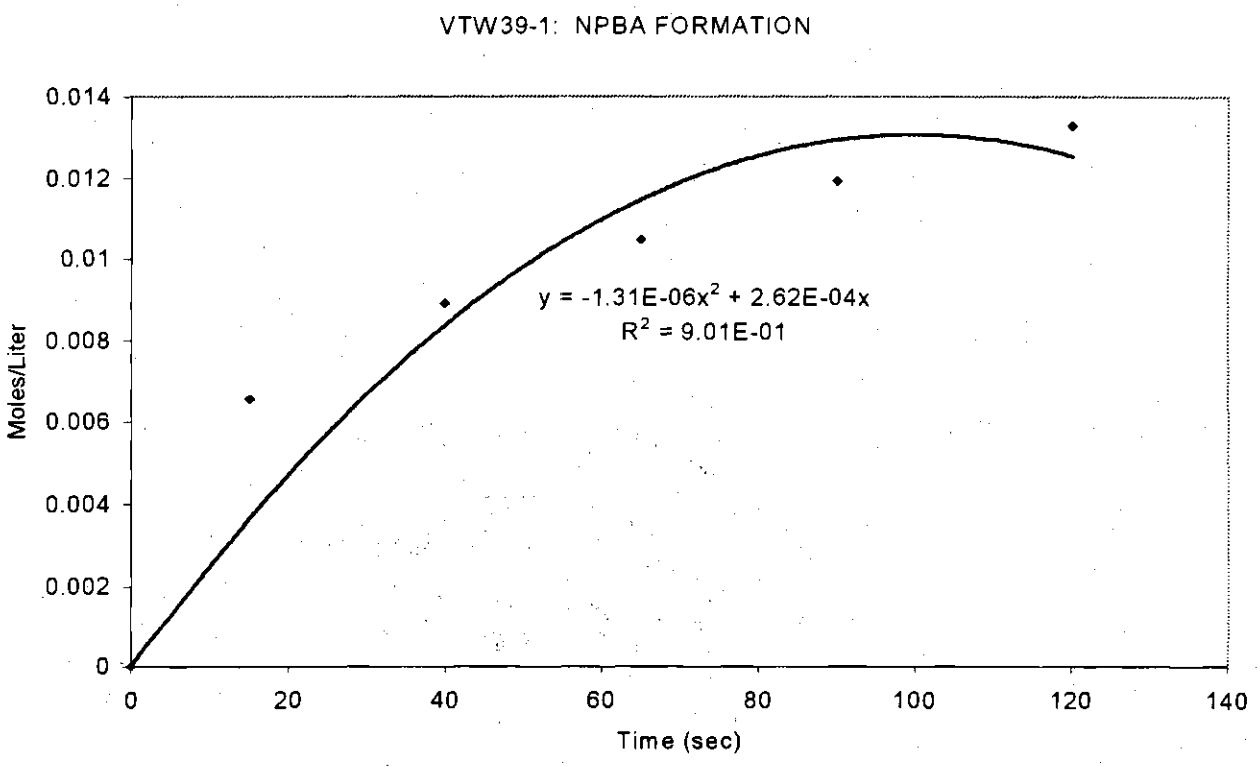


Figure 3.37. N-benzylation of Acetanilide in the Presence of 0.26 M Acetanilide.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.26 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 M KOH	0.0 ml Water	0.0 moles KCl

Table 3.37. N-benzylation of Acetanilide in the Presence of 0.26 M Acetanilide.

TIME (sec)	NPBA
0	0
15	0.0066
40	0.0089
65	0.0105
90	0.0119
120	0.0133
150	0.0148
180	0.0164
240	0.0195
300	0.0217
420	0.0249
600	0.0257
900	0.0257
1200	0.0258
1500	0.0256
2100	0.0257

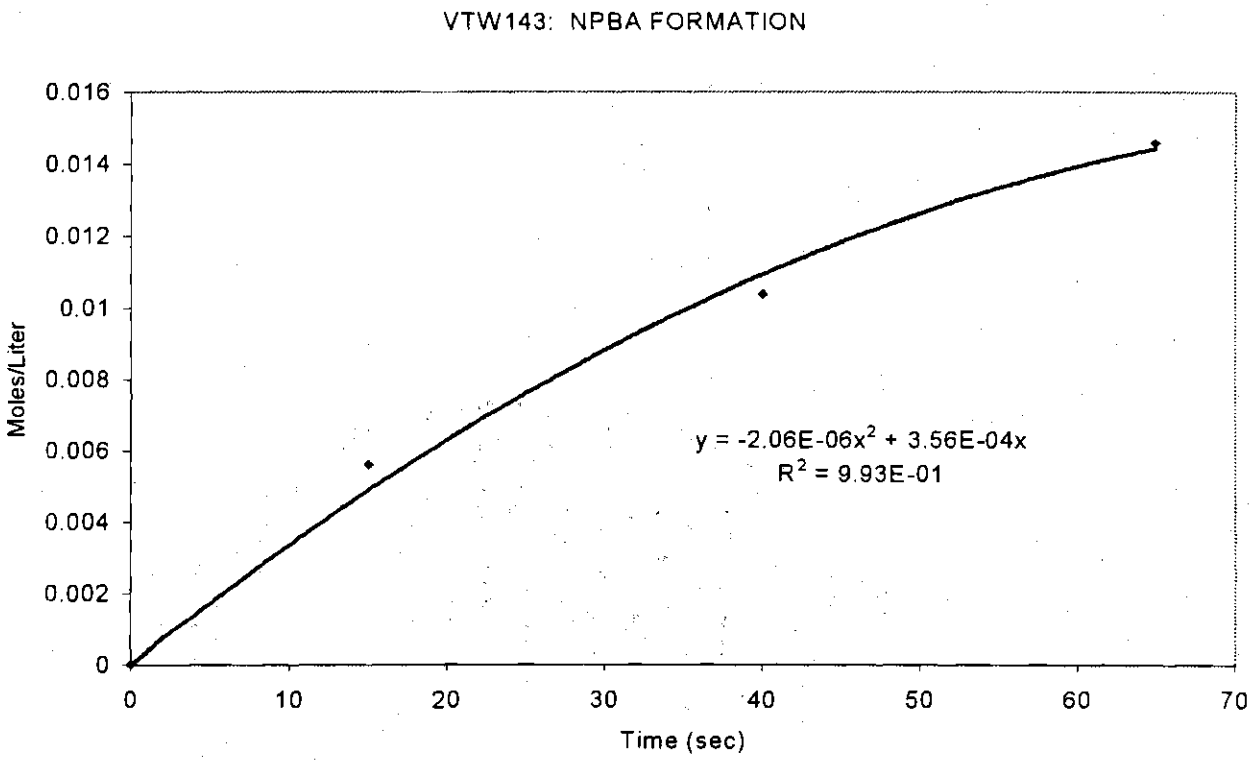


Figure 3.38. N-benzylation of Acetanilide in the Presence of 1.02 M Acetanilide.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
1.02 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 M KOH	0.0 ml Water	0.0 moles KCl

Table 3.38. N-benzylation of Acetanilide in the Presence of 1.02 M Acetanilide.

TIME (sec)	NPBA
0	0
15	0.0056
40	0.0104
65	0.0146
90	0.0182
120	0.0231
180	0.0263
240	0.0286
300	0.0320
420	0.0432
600	0.0401
900	0.0420
1200	0.0433
1500	0.0449
2100	0.0370

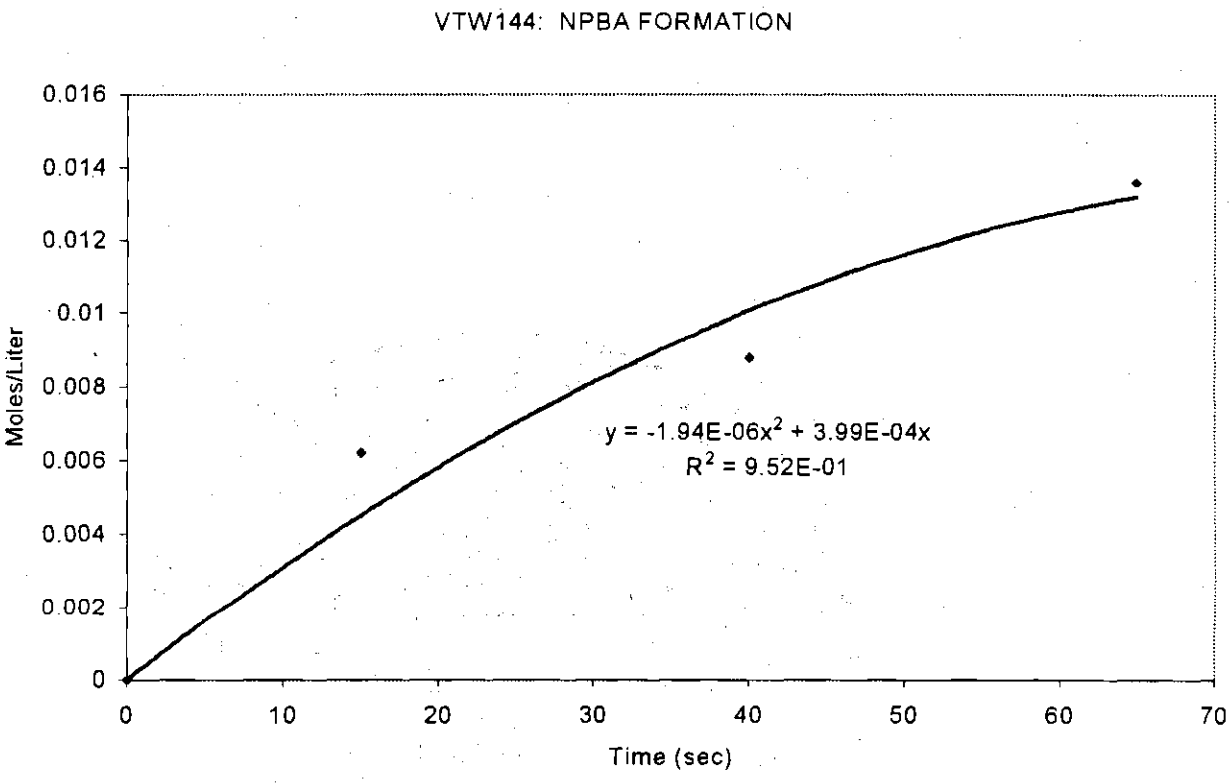


Figure 3.39. N-benzylation of Acetanilide in the Presence of 1.02 M Acetanilide.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
1.02 M Acetanilide	1.04 M Benzyl Chloride	0.051 M TBAC
0.054 M KOH	0.0 ml Water	0.0 moles KCl

Table 3.39. N-benzylation of Acetanilide in the Presence of 1.02 M Acetanilide.

TIME (sec)	NPBA
0	0
15	0.0062
40	0.0088
65	0.0136
90	0.0169
120	0.0183
150	0.0167
180	0.0214
240	0.0226
300	0.0224
420	0.0276
600	0.0298
900	0.0383
1200	0.0392
1500	0.0404
2100	0.0429

Table 3.40. The Effect of Type of Catalyst on Initial Rate

CATALYST, 0.051 M	INITIAL RATE, Mole/Lsec	STANDARD DEVIATION
Benzyltrimethylammonium bromide	5.80×10^{-4}	2.70×10^{-5}
Aliquat 336	4.51×10^{-4}	7.50×10^{-6}
Tetraethylammonium bromide	3.62×10^{-4}	8.00×10^{-6}
Tetra-n-butylammonium chloride	3.39×10^{-4}	3.20×10^{-5}
Tetra-n-heptylammonium bromide	2.72×10^{-4}	1.56×10^{-6}
Tetra-n-octylammonium bromide	2.33×10^{-4}	3.00×10^{-5}

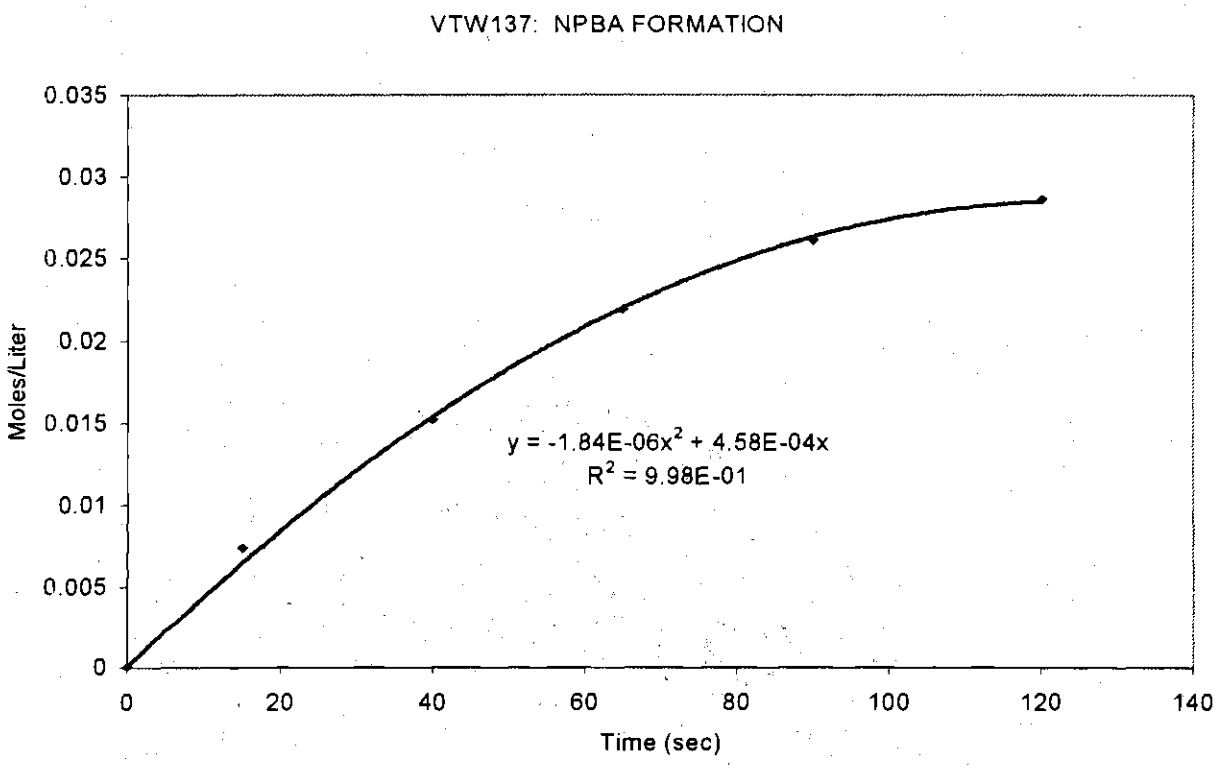


Figure 3.41. N-benzylation of Acetanilide in the Presence of 0.051 M Aliquat 336.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M Aliquat 336**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.41. N-benzylation of Acetanilide in the Presence of 0.051 M Aliquat 336.

TIME (sec)	NPBA
0	0.0
15	0.0074
40	0.0152
65	0.0219
90	0.0261
120	0.0286
150	0.0312
180	0.0323
240	0.0346
300	0.0369
420	0.0407
600	0.0442
1200	0.0468
1500	0.0444
2100	0.0484
2700	0.0483

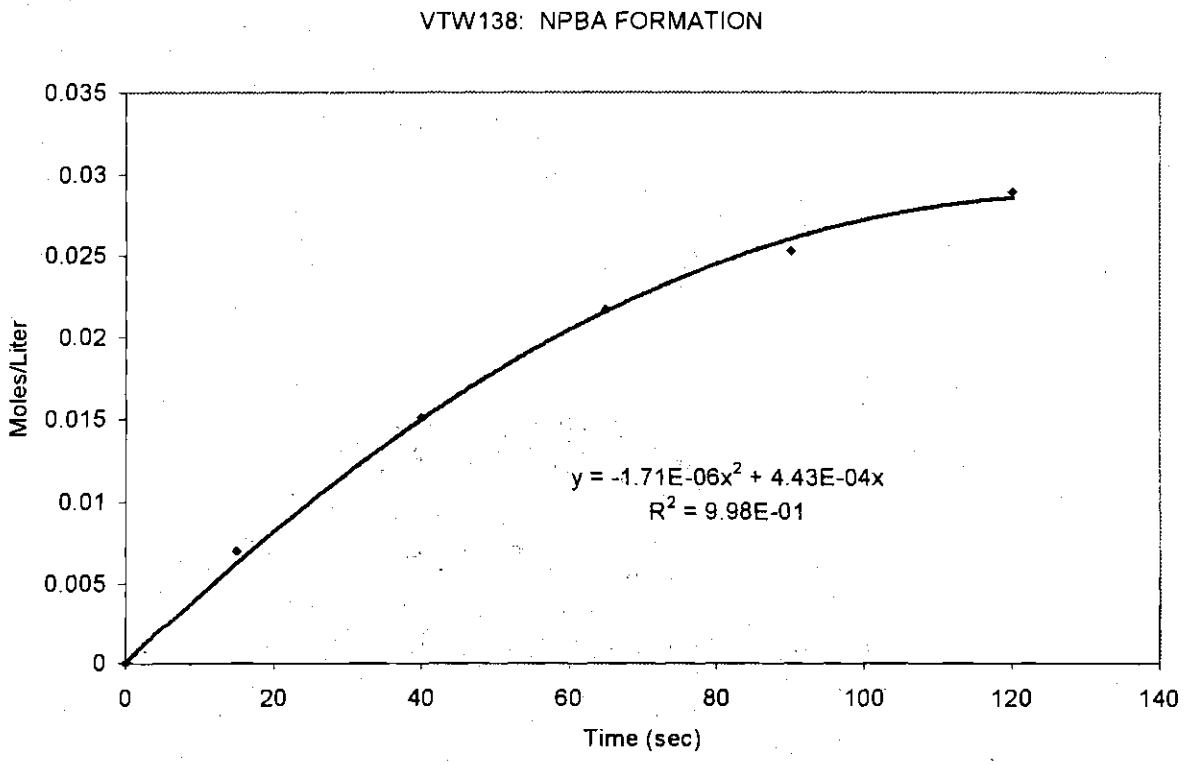


Figure 3.42. N-benzylation of Acetanilide in the Presence of 0.051 M Aliquat 336.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M Aliquat 336**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.42. N-benzylation of Acetanilide in the Presence of 0.051 M Aliquat 336.

TIME (sec)	NPBA
0	0.0
15	0.007
40	0.0151
65	0.0217
90	0.0253
120	0.0289
240	0.0412
300	0.0410
420	0.0437
900	0.0458
1200	0.0468
1500	0.0452
2100	0.0476

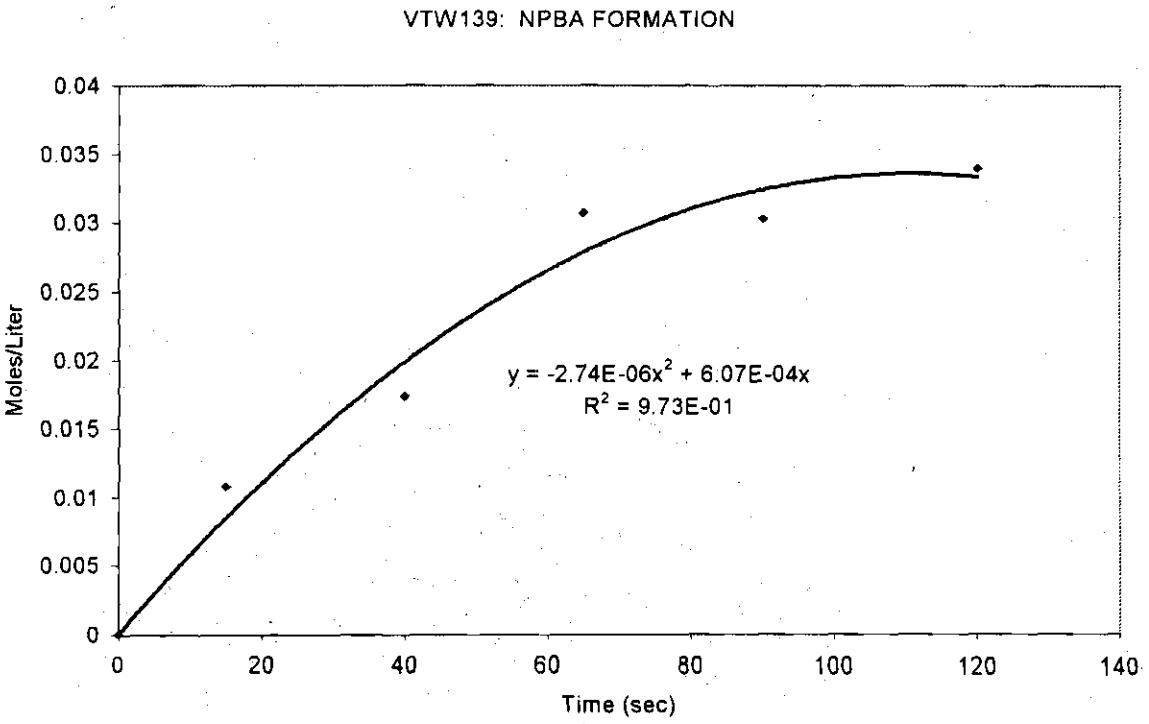


Figure 3.43.. N-benzylation of Acetanilide in the Presence of 0.051 M BTMB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M BTMB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.43. N-benzylation of Acetanilide in the Presence of 0.051 M BTMB.

TIME (sec)	NPBA
0	0.0
15	0.0108
40	0.0174
65	0.0307
90	0.0303
120	0.0340
150	0.0336
240	0.0336
600	0.0394
2100	0.0404
2700	0.0382
3600	0.0455

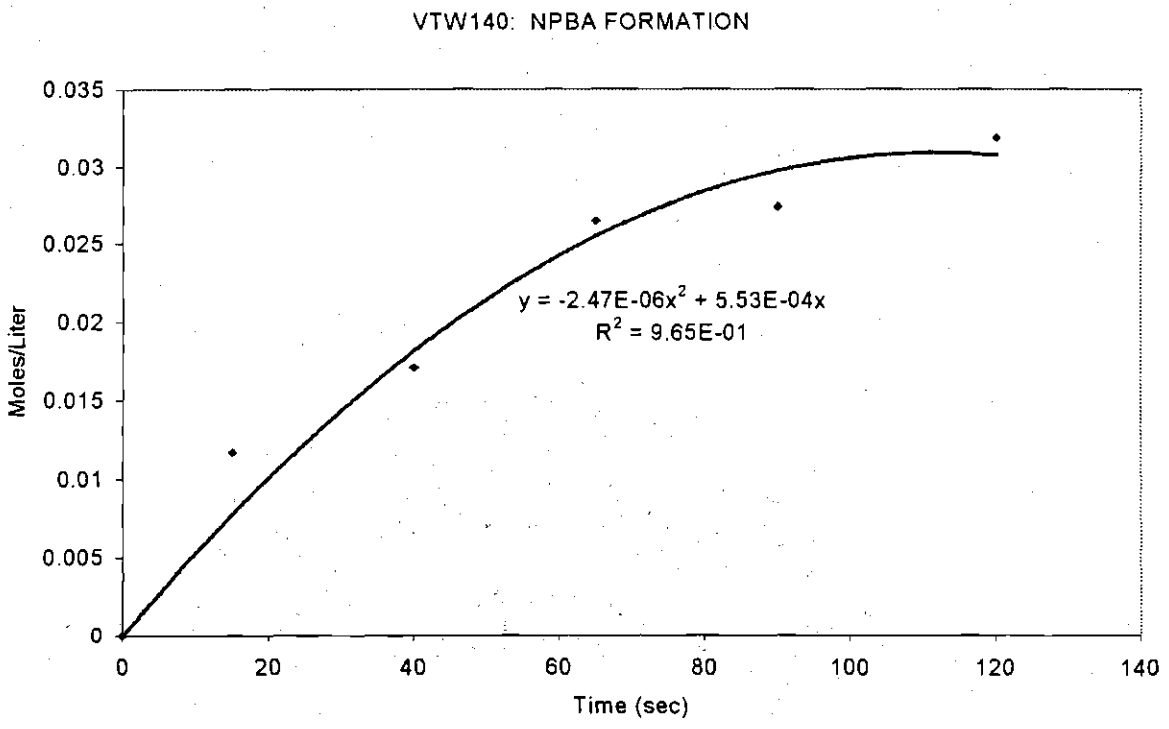


Figure 3.44. N-benzylation of Acetanilide in the Presence of 0.051 M BTMB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M BTMB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.44. N-benzylation of Acetanilide in the Presence of 0.051 M BTMB.

TIME (sec)	NPBA
0	0.0
15	0.0117
40	0.0171
65	0.0265
90	0.0274
120	0.0319
150	0.0308
180	0.0329
420	0.0365
900	0.0383
2100	0.0403
2700	0.0408

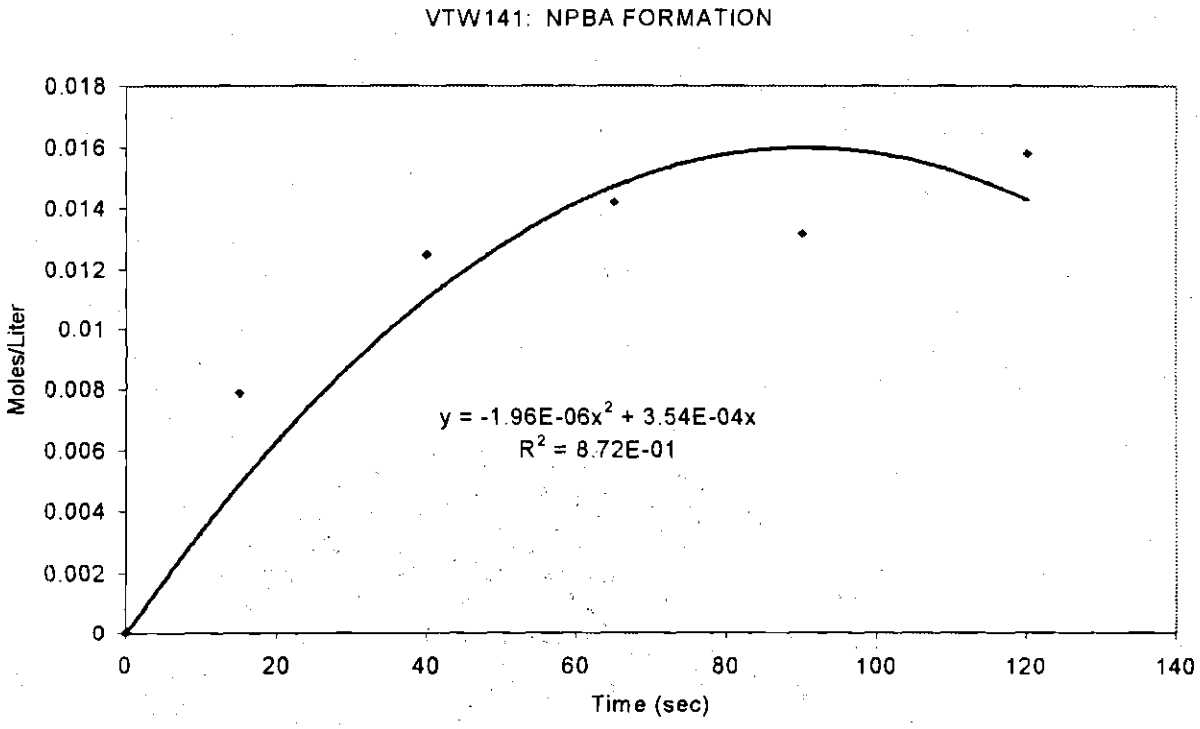


Figure 3.45. N-benzylation of Acetanilide in the Presence of 0.051 M TEAB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M TEAB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.45. N-benzylation of Acetanilide in the Presence of 0.051 M TEAB.

TIME (sec)	NPBA
0	0.0
15	0.0079
40	0.0125
65	0.0142
90	0.0132
120	0.0158
150	0.0165
180	0.0202
240	0.0186
300	0.0205
420	0.0250
600	0.0274
1200	0.0374
1500	0.0373
2100	0.0360
2700	0.0359

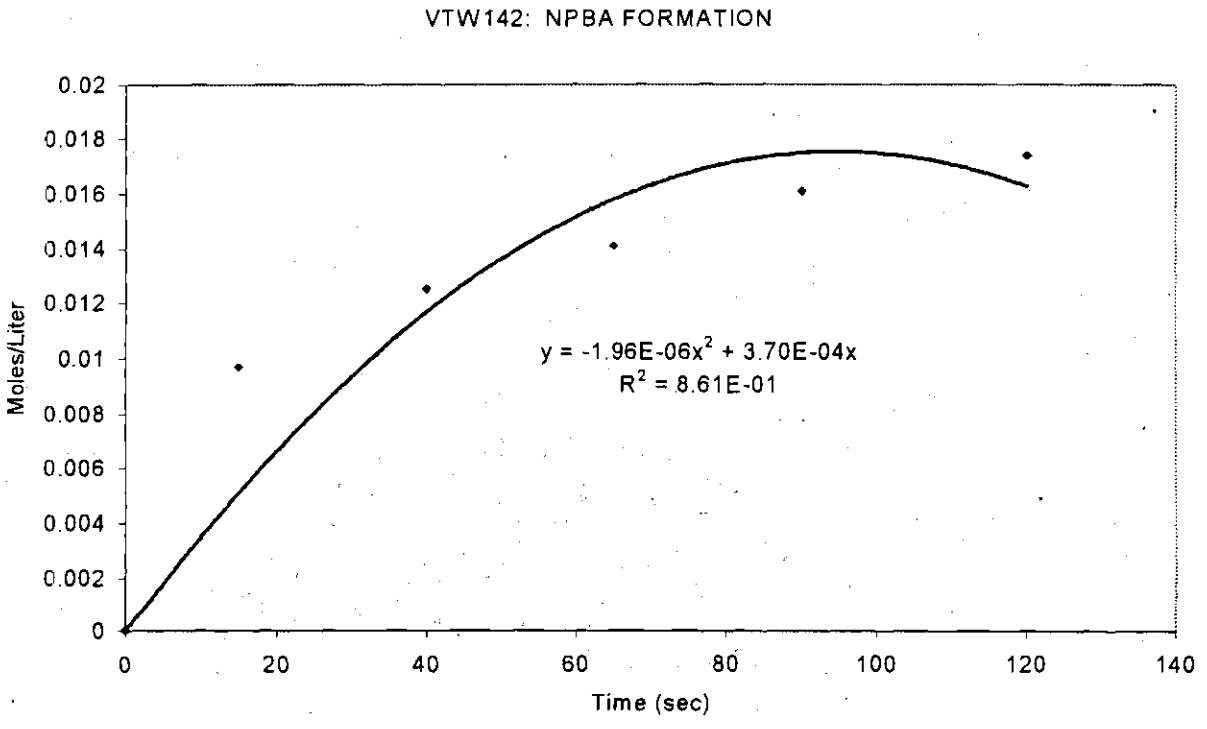


Figure 3.46. N-benzylation of Acetanilide in the Presence of 0.051 M TEAB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M TEAB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.46. N-benzylation of Acetanilide in the Presence of 0.051 M TEAB.

TIME (sec)	NPBA
0	0.0
15	0.0097
40	0.0125
65	0.0141
90	0.0161
120	0.0174
150	0.0170
180	0.0195
300	0.0226
420	0.0254
600	0.0303
1200	0.0375
1500	0.0426
2100	0.0460
2700	0.0433

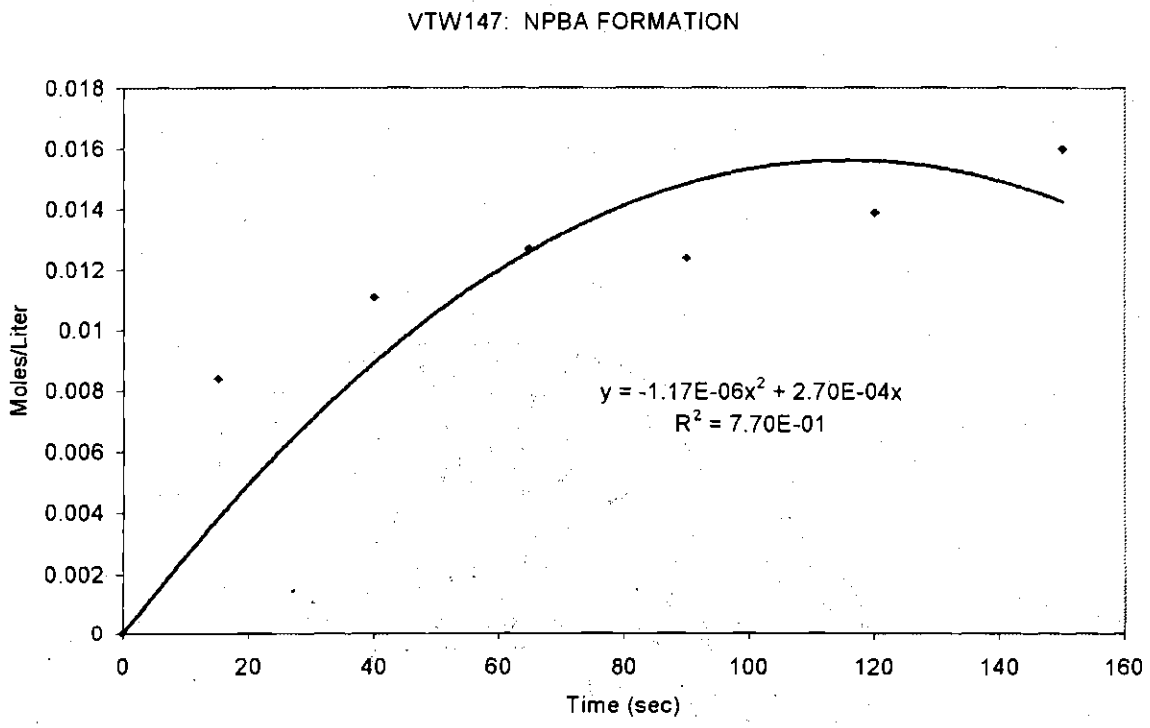


Figure 3.47. N-benzylation of Acetanilide in the Presence of 0.051 M THAB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M THAB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.47. N-benzylation of Acetanilide in the Presence of 0.051 M THAB.

TIME (sec)	NPBA
0	0.0
15	0.0084
40	0.0111
65	0.0127
90	0.0124
120	0.0139
150	0.0160
180	0.0175
240	0.0183
300	0.0238
420	0.0274
600	0.0347
900	0.0388
1200	0.0383
1500	0.0405
2100	0.0419
2700	0.0418
3600	0.0411

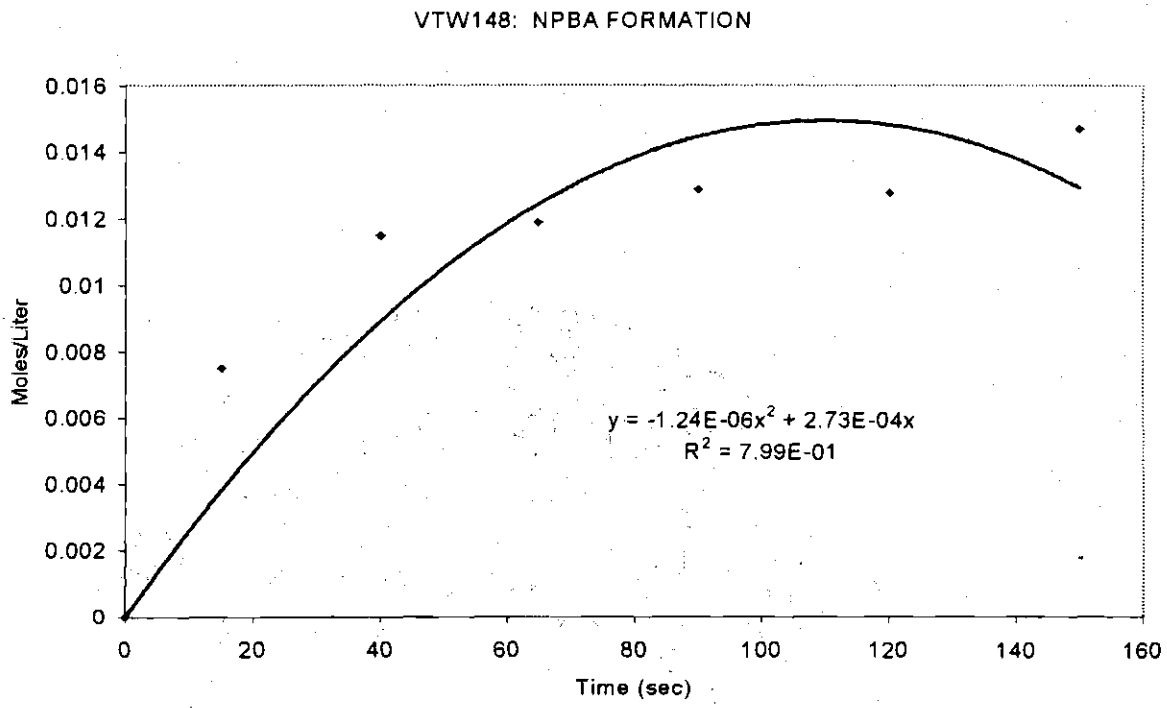


Figure 3.48. N-benzylation of Acetanilide in the Presence of 0.051 M THAB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M THAB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.48. N-benzylation of Acetanilide in the Presence of 0.051 M THAB.

TIME (sec)	NPBA
0	0.0
15	0.0075
40	0.0115
65	0.0119
90	0.0129
120	0.0128
150	0.0147
180	0.0152
240	0.0181
300	0.0167
420	0.0238
600	0.0297
900	0.0337
1200	0.0362
1500	0.0429
2100	0.0420
2700	0.0433
3600	0.0427

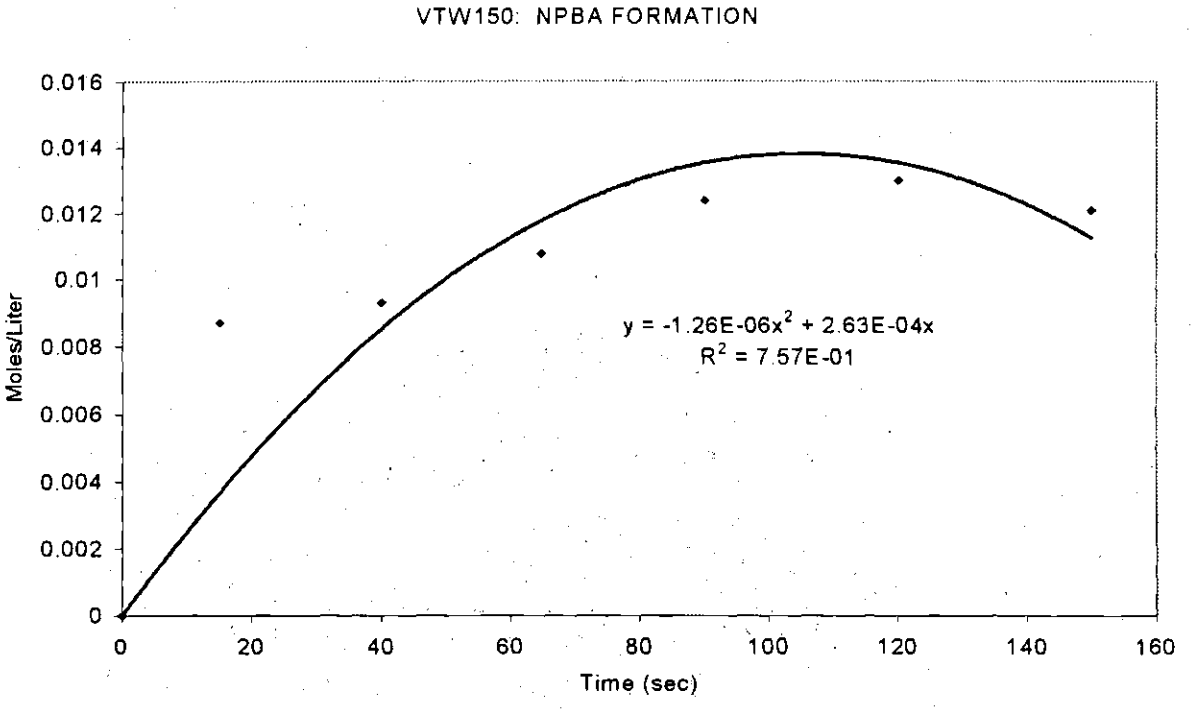


Figure 3.49. N-benzylation of Acetanilide in the Presence of 0.051 M TOAB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M TOAB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.49. N-benzylation of Acetanilide in the Presence of 0.051 M TOAB.

TIME (sec)	NPBA
0	0.0
15	0.0087
40	0.0093
65	0.0108
90	0.0124
120	0.0130
150	0.0121
180	0.0125
240	0.0161
300	0.0188
420	0.0214
600	0.0301
900	0.0314
1200	0.0380
1500	0.0415
2100	0.0479
2700	0.0446
3600	0.0441

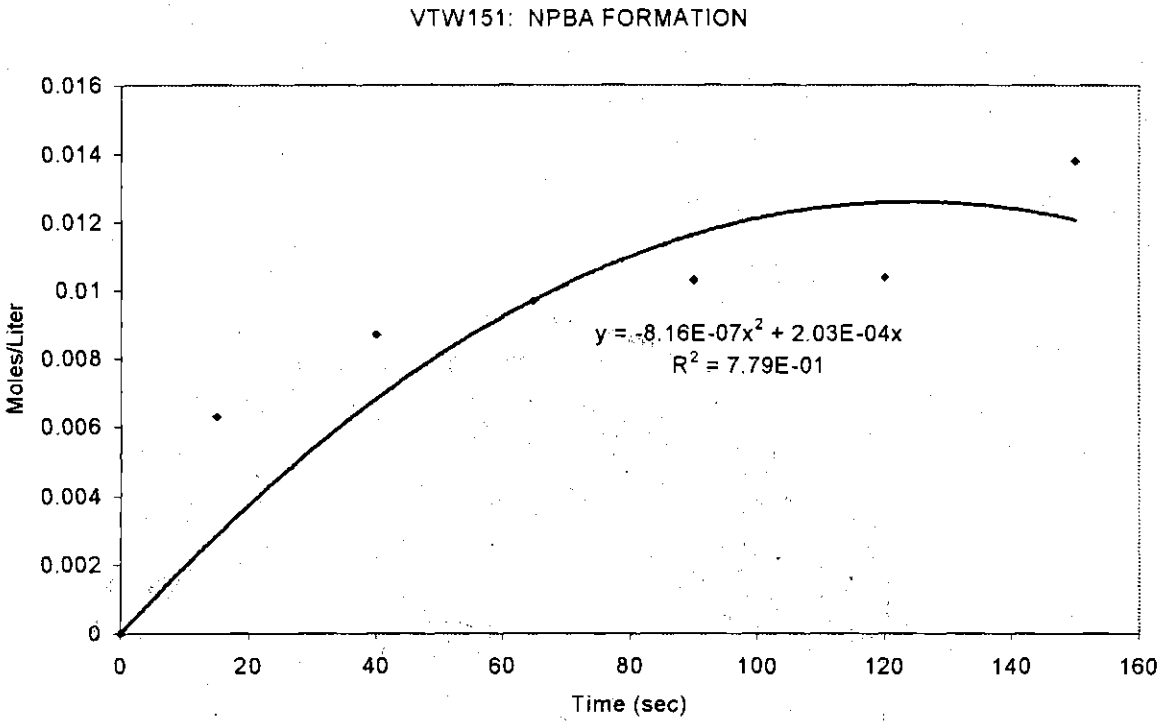


Figure 3.50. N-benzylation of Acetanilide in the Presence of 0.051 M TOAB.

REACTION CONDITIONS		
100 ml o-dichlorobenzene	78°C	Stir Rate = 840 rpm
0.051 M Acetanilide	1.04 M Benzyl Chloride	**0.051 M TOAB**
0.054 moles KOH	0.0 ml Water	0.0 moles KCl

Table 3.50. N-benzylation of Acetanilide in the Presence of 0.051 M TOAB.

TIME (sec)	NPBA
0	0.0
15	0.0063
40	0.0087
65	0.0097
90	0.0103
120	0.0104
150	0.0138
240	0.0174
300	0.0195
420	0.0263
1200	0.0385
1500	0.0503
2100	0.0471
2700	0.0445
3600	0.0456

References

1. (a) Liotta, C. L., Starks, C. M., Halpern, M. E.; *Phase-Transfer Catalysis*, Wiley Science (1995). (b) Dehmlow, *Angew. Chem. Int. Eng. Ed.* **13**, *170*, (1974).

2. Hodgson, Jr., United States Patent, 4,366,158, (1982).

3. (a) Gaino, M., United States Patent, 4,438,035, (1984). (b) Cardizem CD prescribing information (1995)

4. Lisi, A., Martinez, J., Schill, G.; *J. Chromatography*, **563**, *257*, (1991).

5. Kalkote, U. R., Choudhary, A. R., Ayyangar, N. R., *OPPI Briefs*, **24**, *83*, (1992).

6. Liotta, C. L., Eckert, C. A., Boatright, D. L., Suleiman, D., Yun, S. C. J., Dillow, A. K., *Industrial & Engineering Chemical Research*, **35**, *1801*, (1996).

7. Liotta, C. L., Starks, C. M., Halpern, M. E.; *Phase Transfer Catalysis in Industry -4th Annual Short Course*, PTC Interface, Inc, (1995).

8. (a) Liotta, C. L., Burgess, E. M., Ray, C. C, Black, E. D., Fair, B. E., ACS Symposium Series 326, Starks (ed)., *15*, (1987); (b) Liotta, C. L. , Fair, B. E., Berkner, J., Wright, J. ACS Monograph Series (in Press) (c) Fair, B. E., Ph.D. Dissertation, Georgia Institute of Technology (1985); (d) Hurley, J. F., Ph.D Dissertation, Georgia Institute of Technology (1992); (e) Boatright, D, Ph.D. Dissertation, Georgia Institute of Technology (1996).

9. Wright, J. T., Ph.D Dissertation, Georgia Institute of Technology (1996)

10. Landini, D., Angelamaria, M., Alessandro, R.; *J. Org Chem*, **51**, *3187*, (1986).